

# Netter's Atlas of Human Embryology

Larry Cochard



*F. Netter  
M.D.*

# AN OVERVIEW OF DEVELOPMENTAL EVENTS, PROCESSES, AND ABNORMALITIES: TIMELINE

Prenatal Time Scale (Months)

First 2 weeks



Blastocyst

1

Main Embryonic Period

Embryo



2

This is a period of cell proliferation from the zygote to the morula, blastocyst, and formation of the bilaminar embryonic disc. Birth defects do not originate in this period because body systems and structures have not yet developed. Teratogens usually cause the loss of the entire conceptus.

Weeks 3 to 8 is the dynamic period of gastrulation, folding of the embryo, and the formation of all the organ systems. Because this is the most active period of development and differentiation, the embryo in weeks 3 to 8 is most vulnerable to major birth defects.

3

4

Fetal Period



5

Fetus

6

Months 3 to 9 (full term) are mainly characterized by the growth of all the major structures that have already appeared. Birth defects in this period are usually not as severe or obvious and include small size, mental retardation, and defects in the eyes, ears, teeth, and external genitalia.

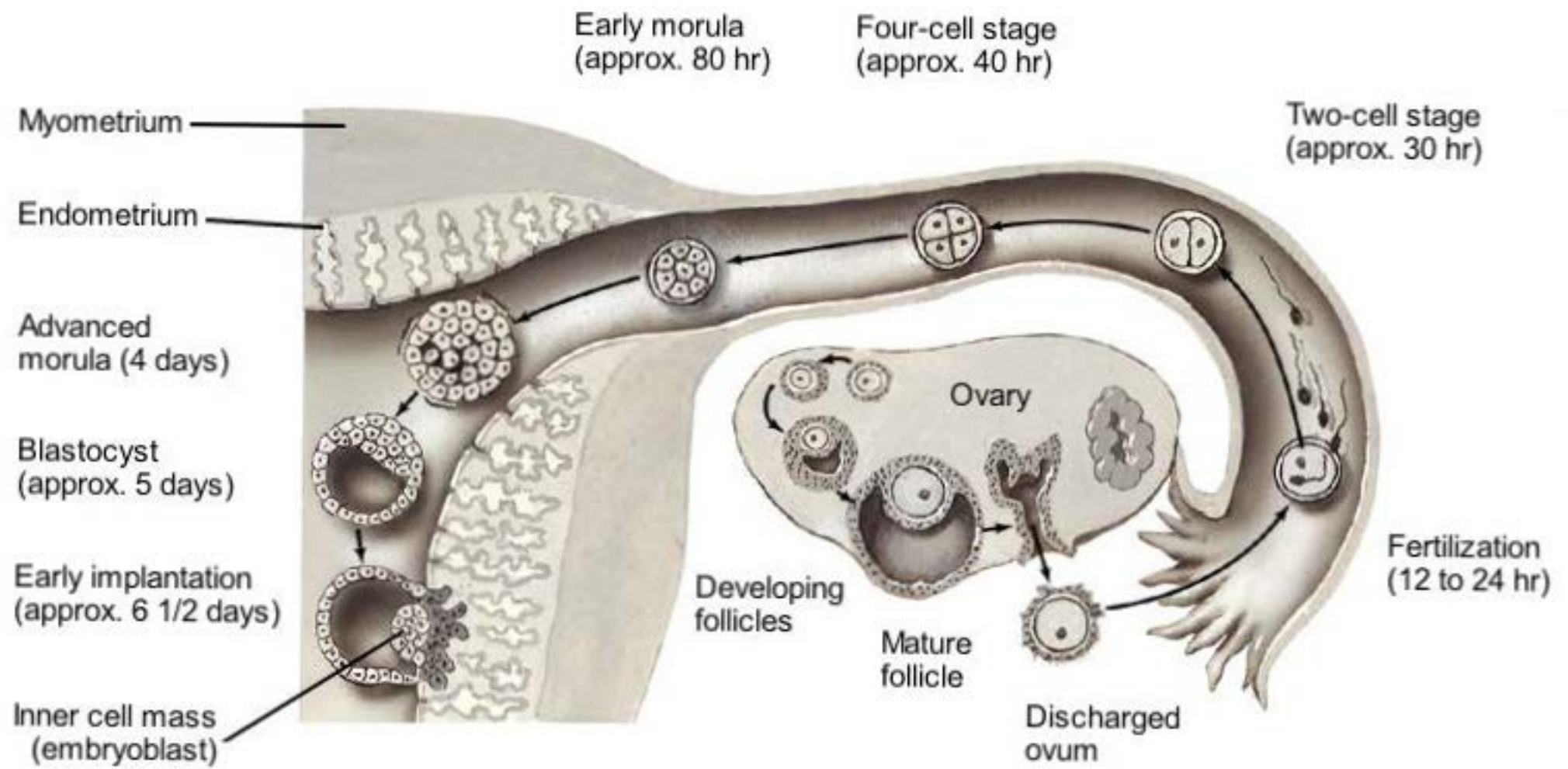
7

8

9

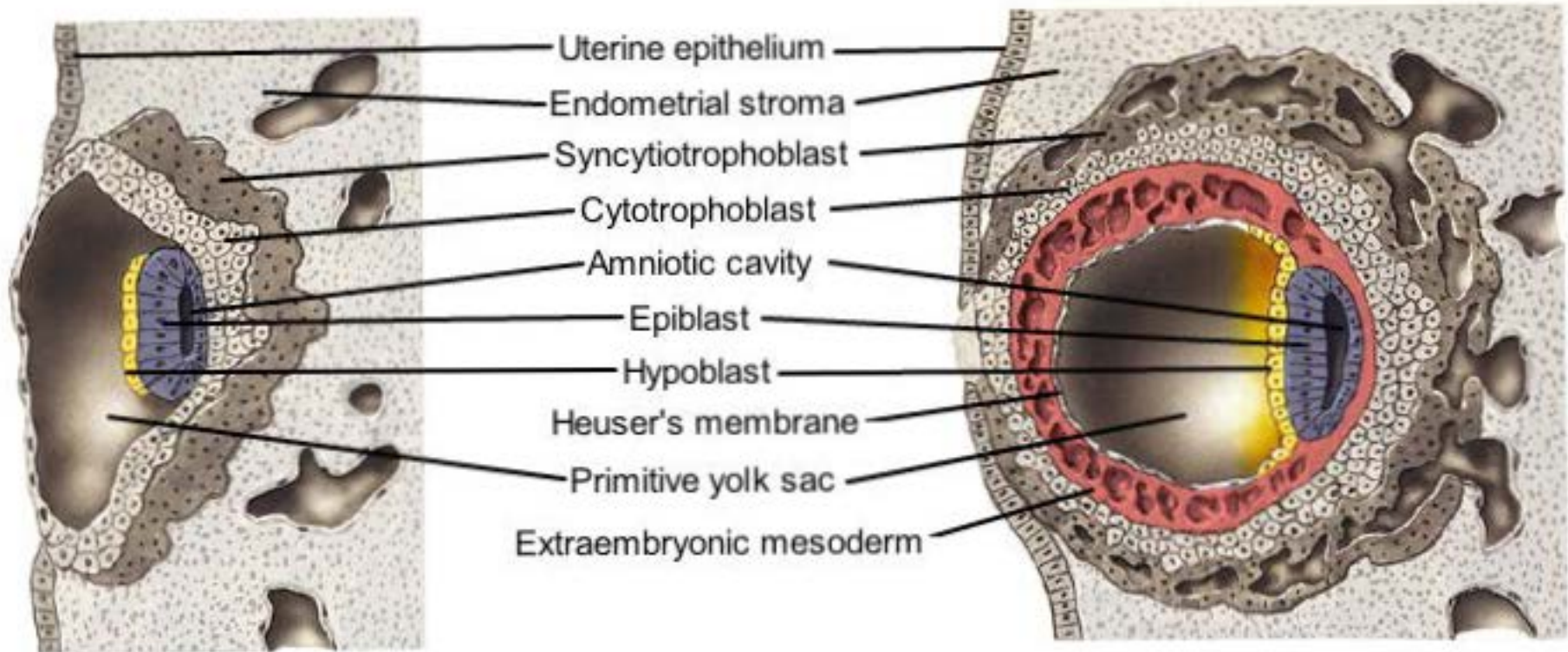
Birth

# The First Week



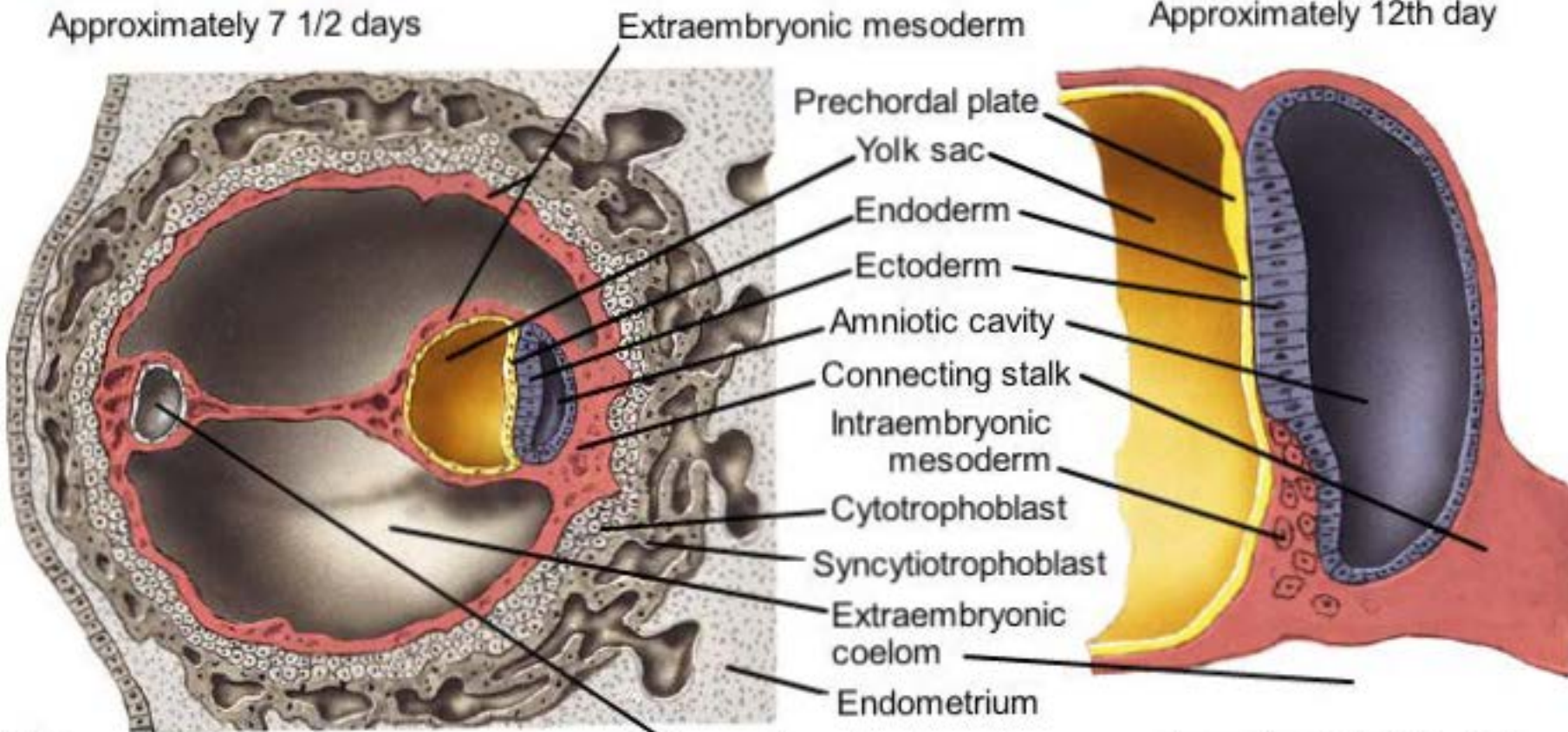


# The Second Week



Approximately 7 1/2 days

Approximately 12th day



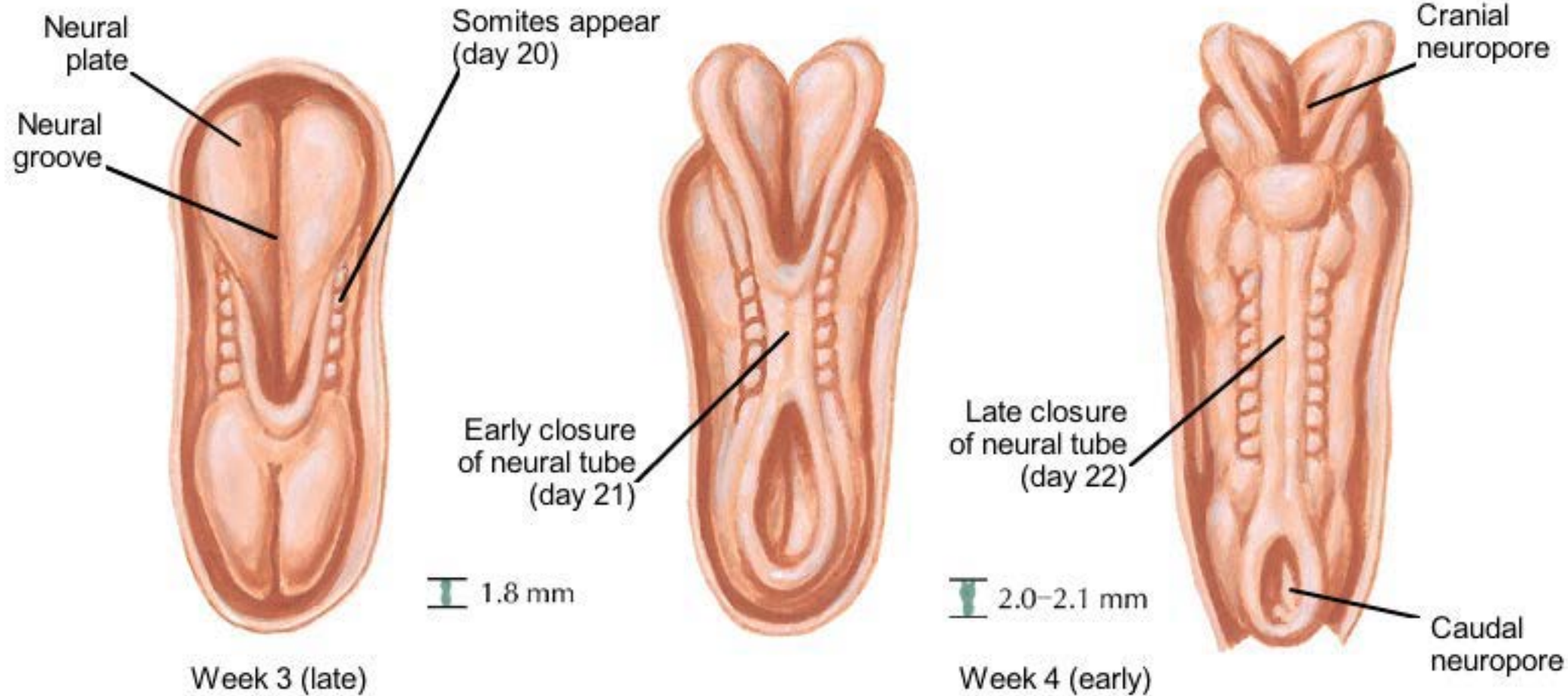
Approximately 15th day

Approximately 17th day



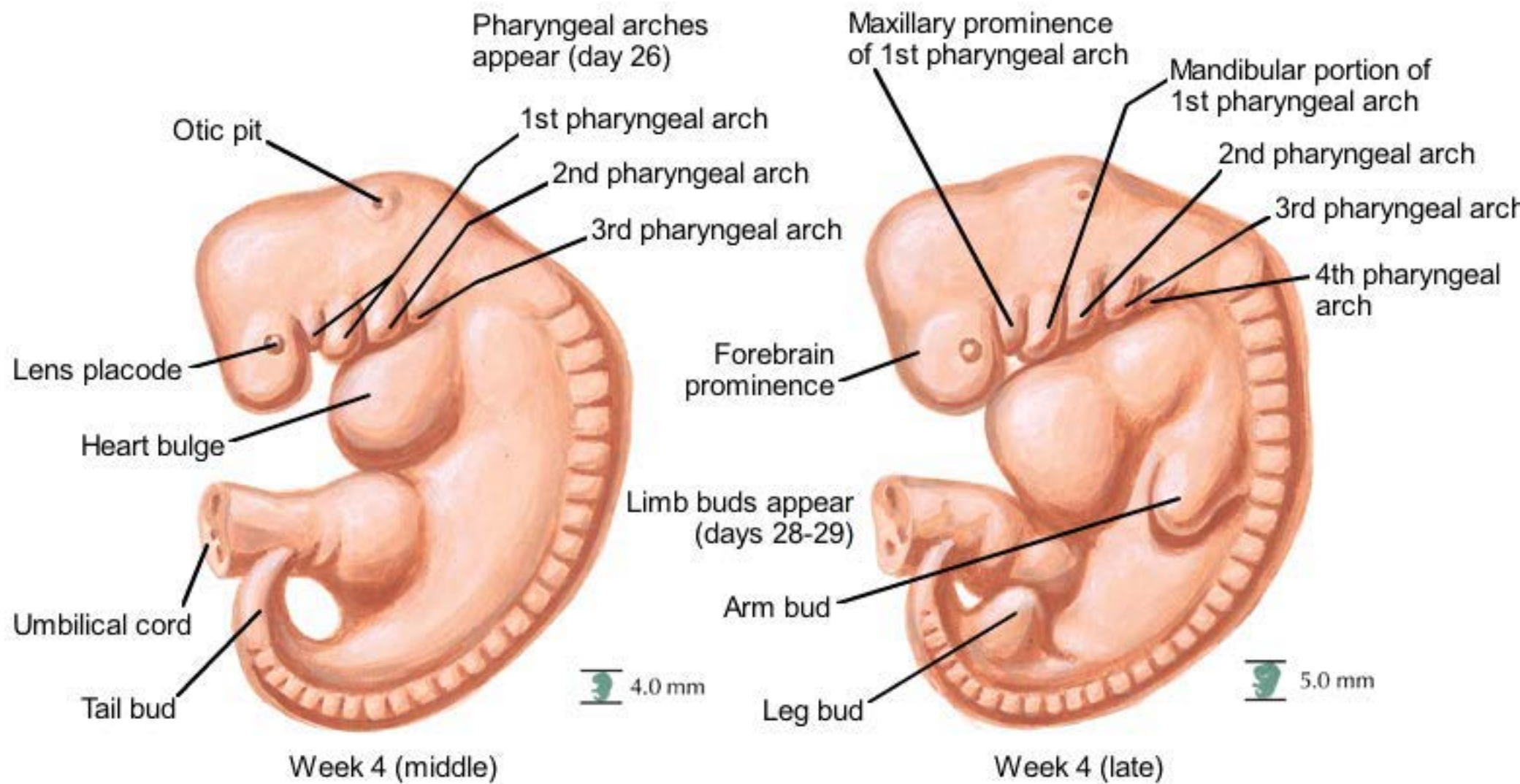
# The Embryonic Period

## Dorsal Views



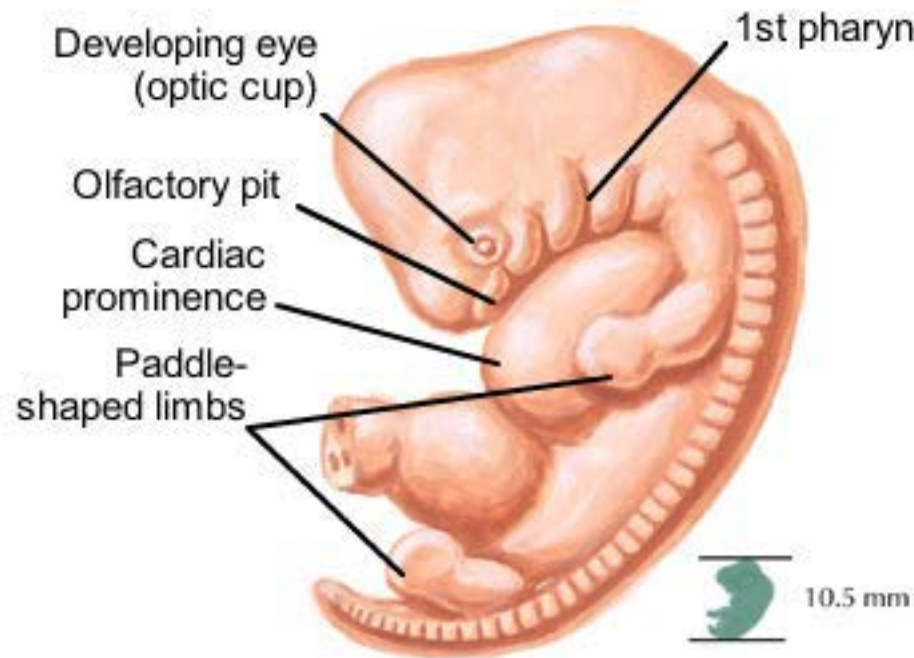
# The Embryonic Period

## Sagittal Views

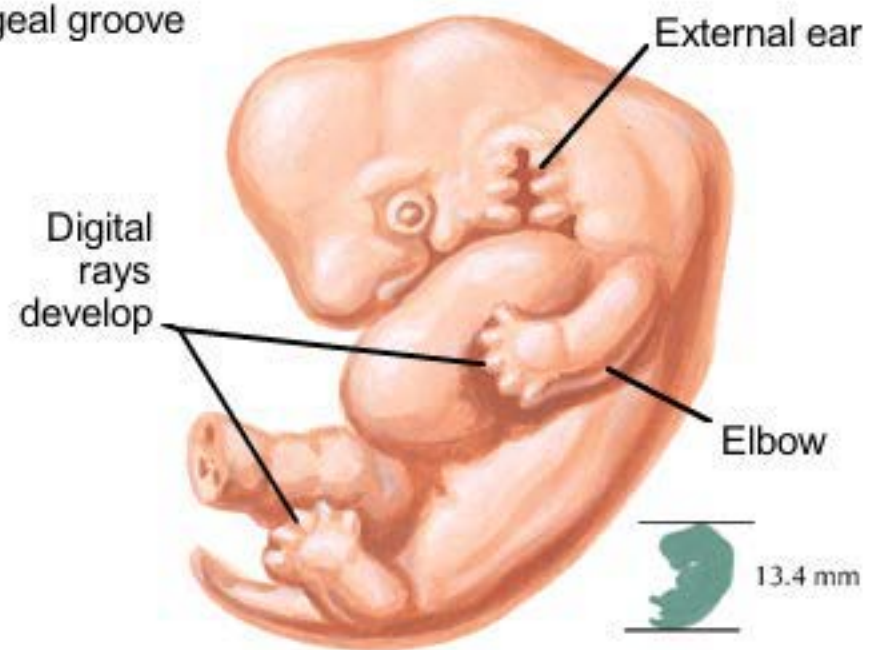




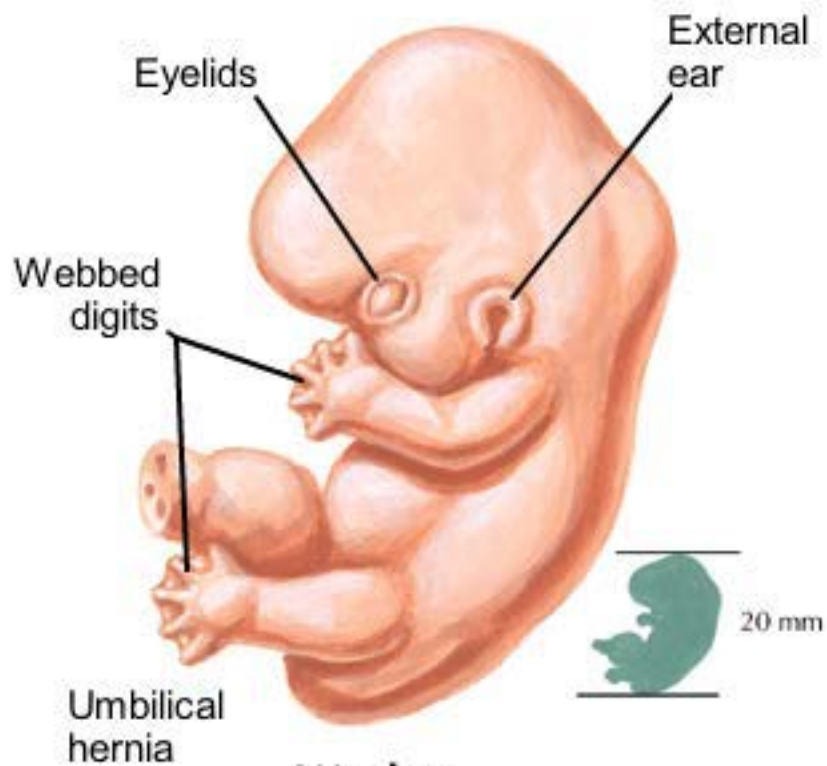
# The Embryonic Period



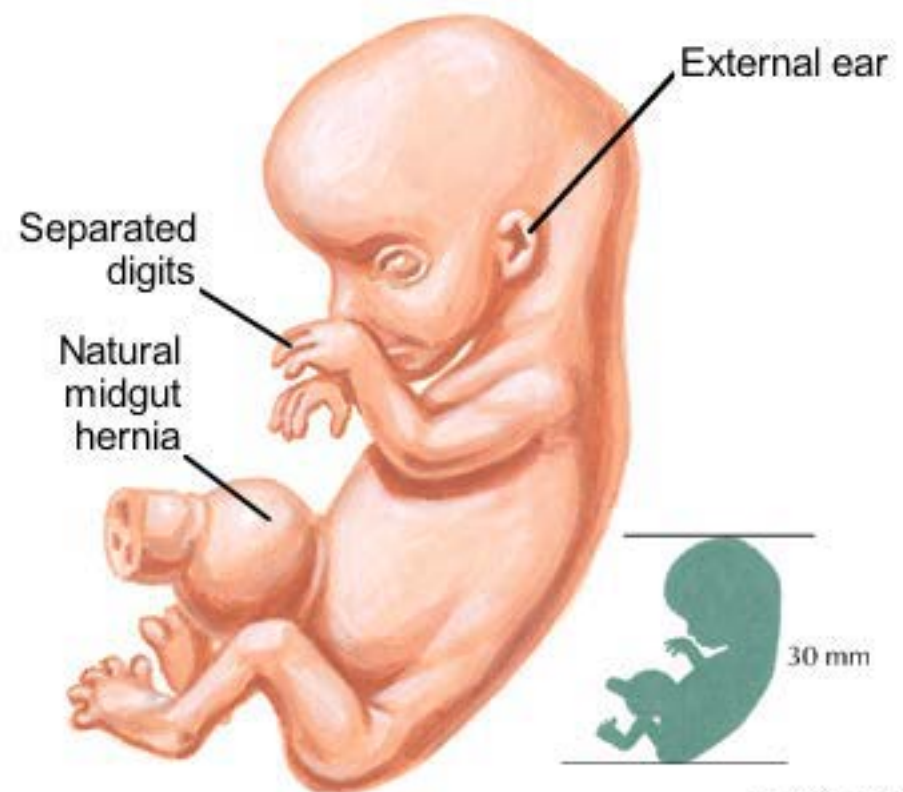
Week 5 (late)



Week 6 (early)



Week 7



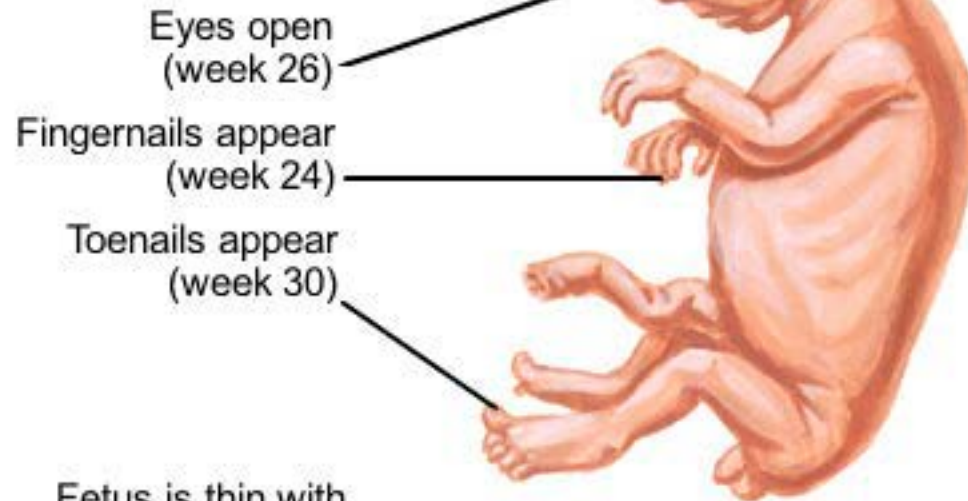
Week 8

# The Fetal Period



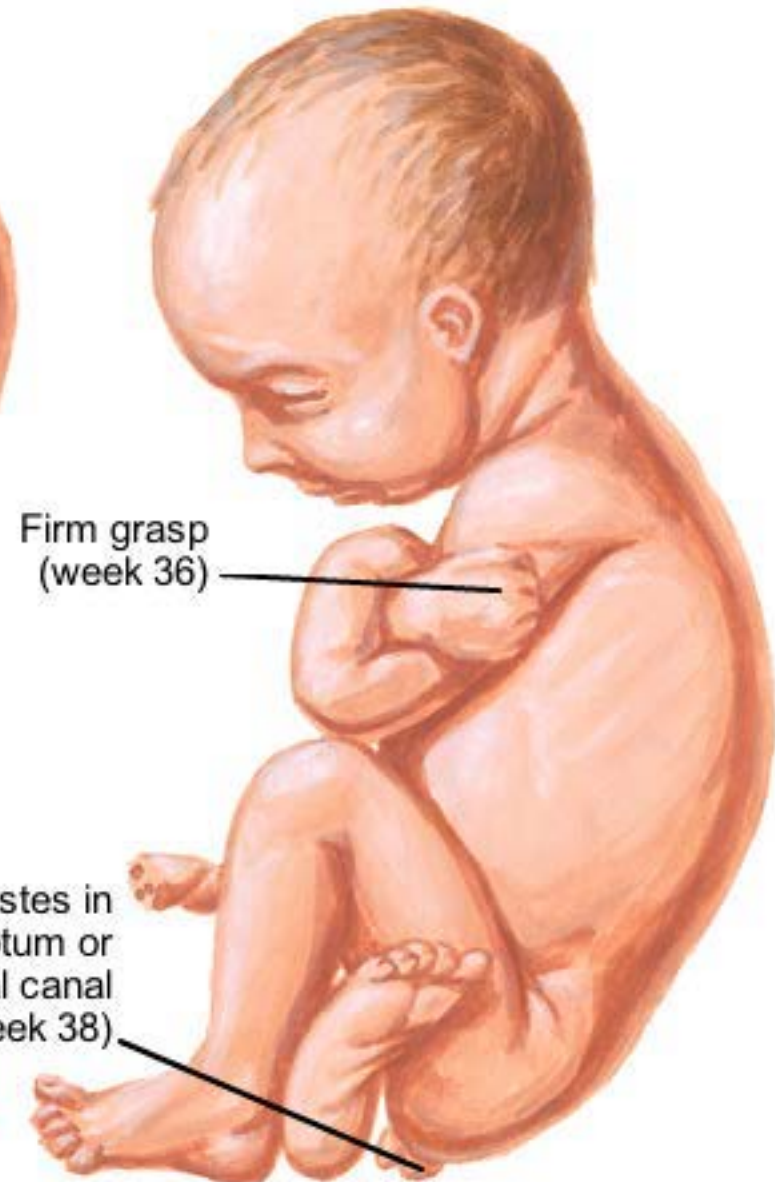
**Note: CRL=5 crown-to-rump length**

**Early fetal period**  
(week 8-week 16  
CRL 5.0-14 cm)



Fetus is thin with little body fat. Fetus viable by week 22

**Middle fetal period**  
(week 17-week 30  
CRL 15-28 cm)



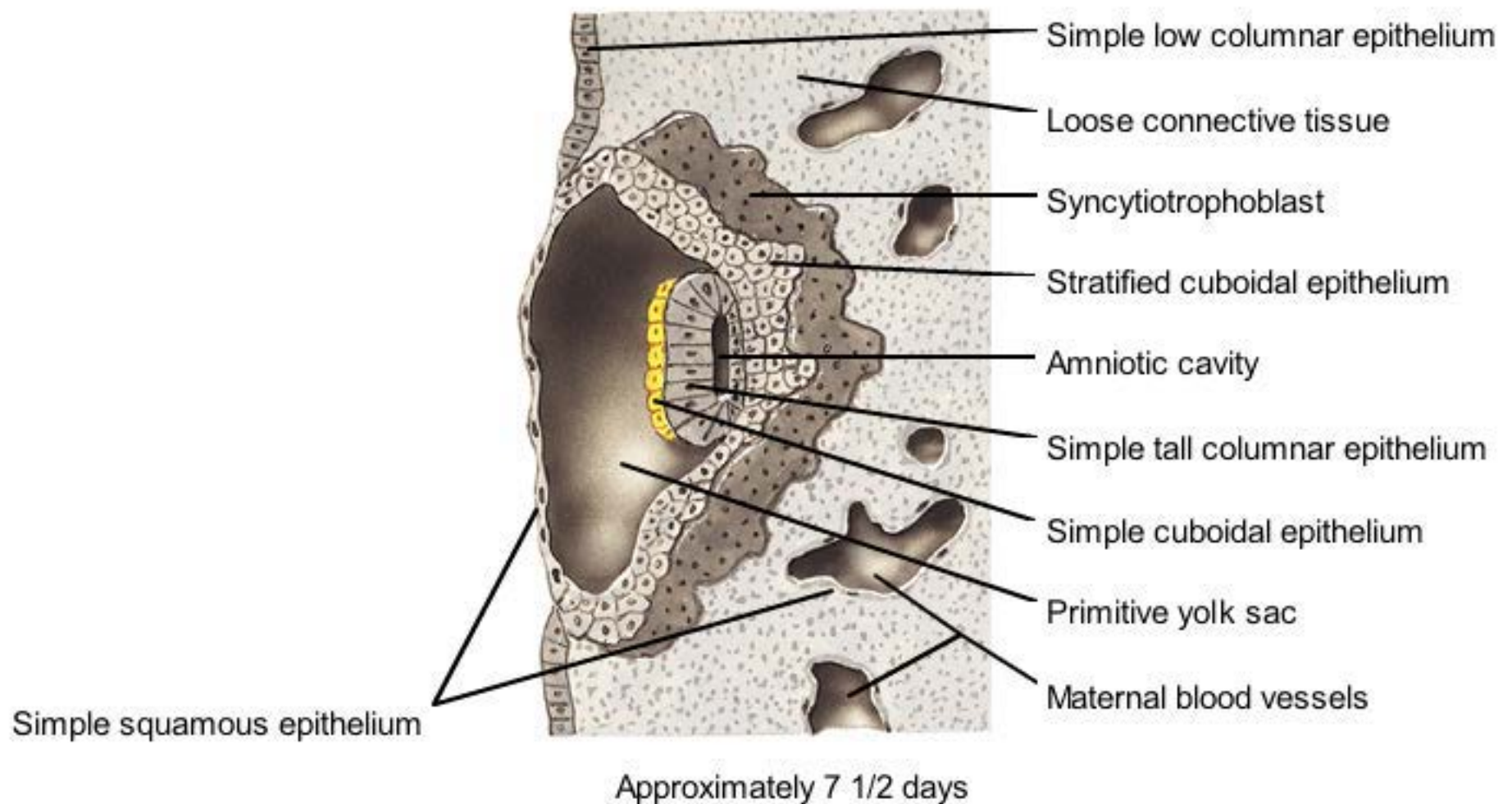
Rapid weight gain and fat deposition beginning in week 32 results in typical "plump" appearance of term fetus

**Late fetal period**  
(week 31-week 38  
CRL 28-36 cm)



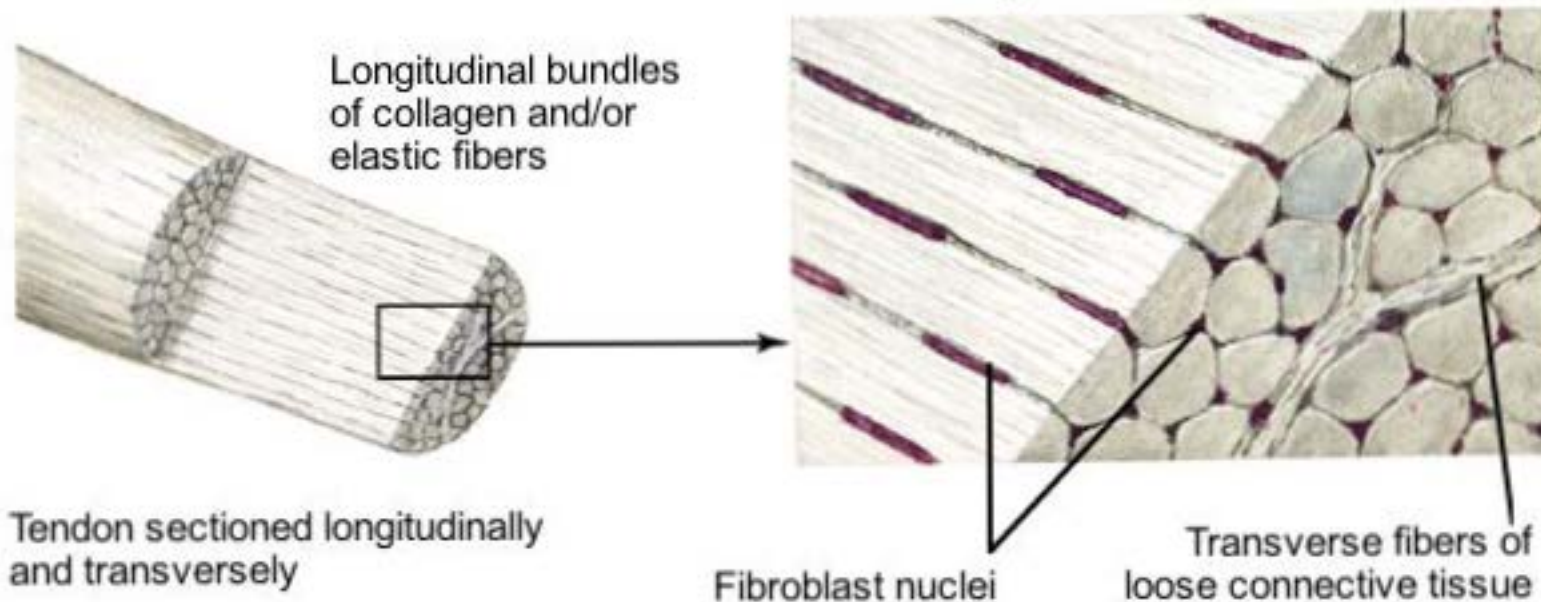
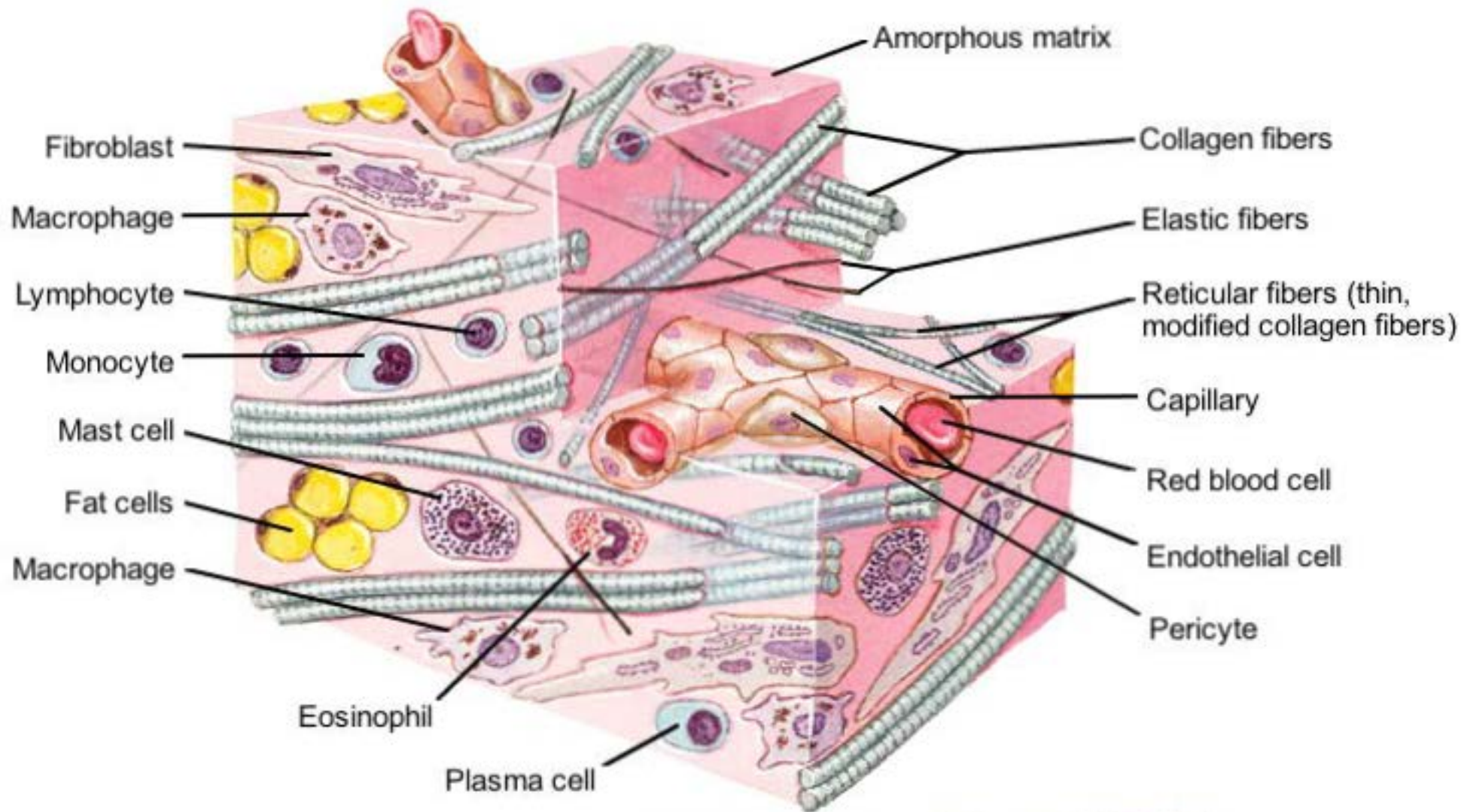
# Histological Concepts

## Blastocyst with embryo within the uterine mucosa



# Histological Concepts

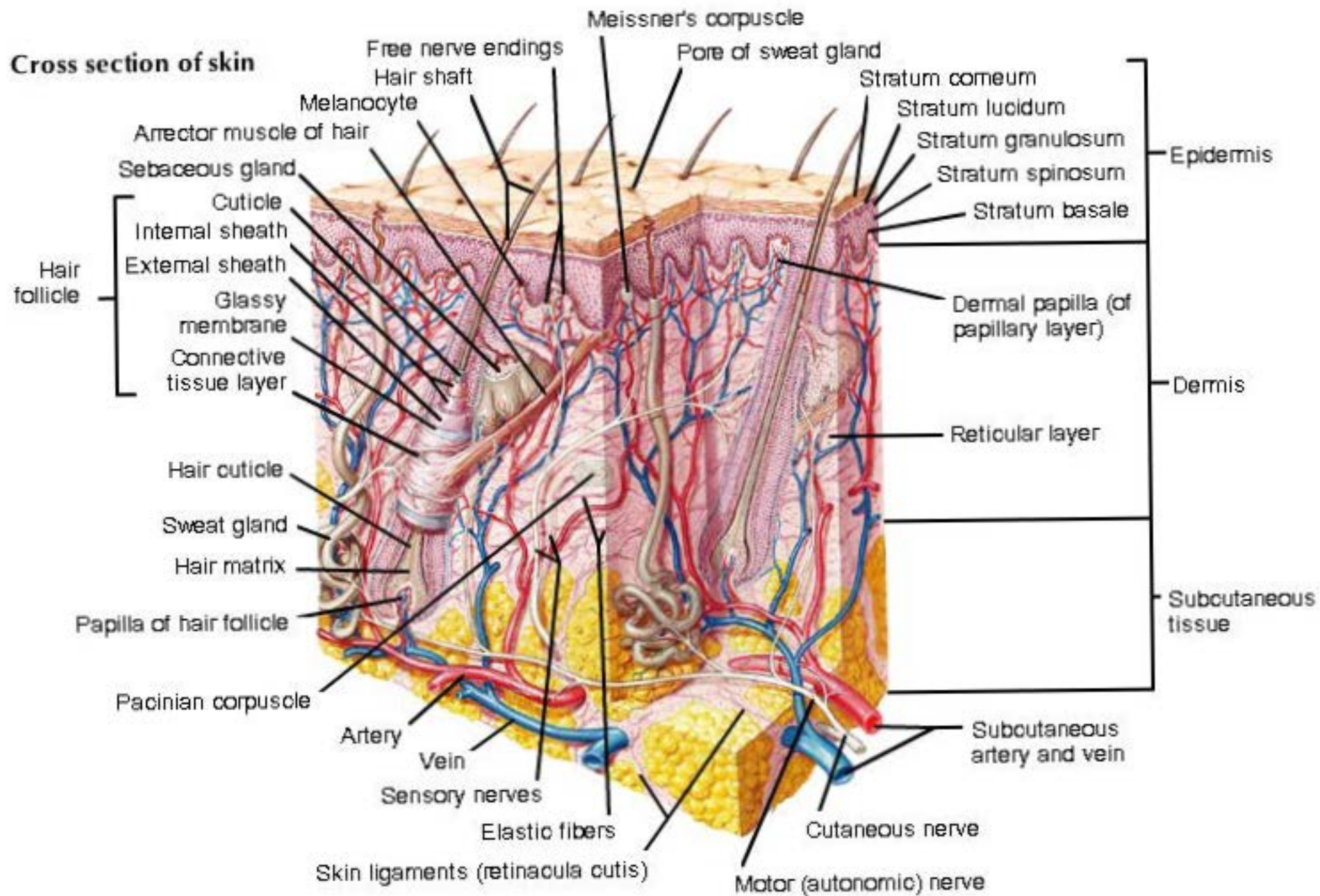
## Loose and dense connective tissue



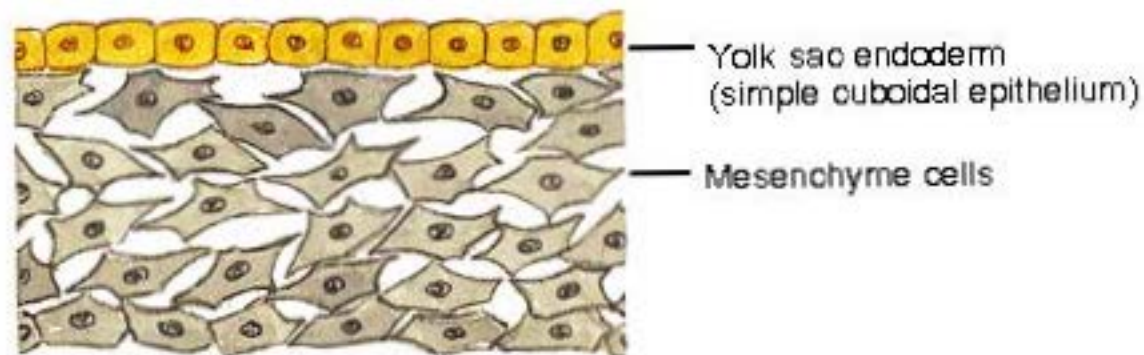


# Histological Concepts

## Cross section of skin

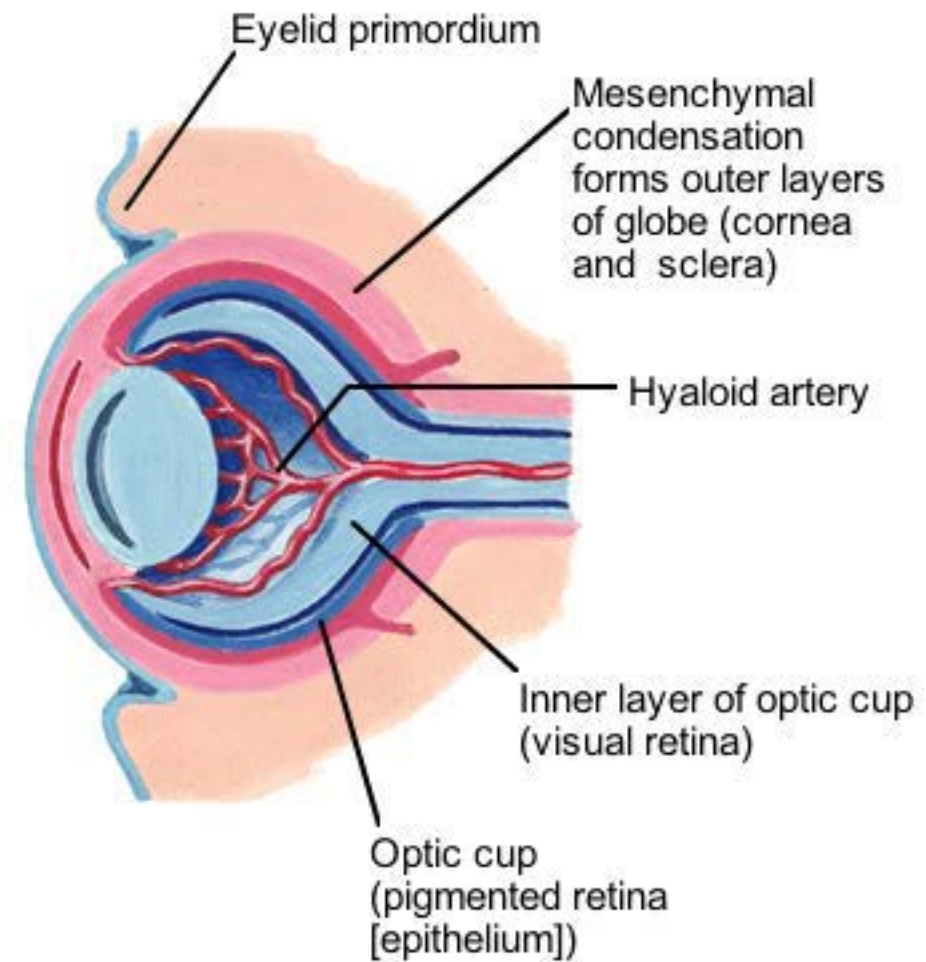
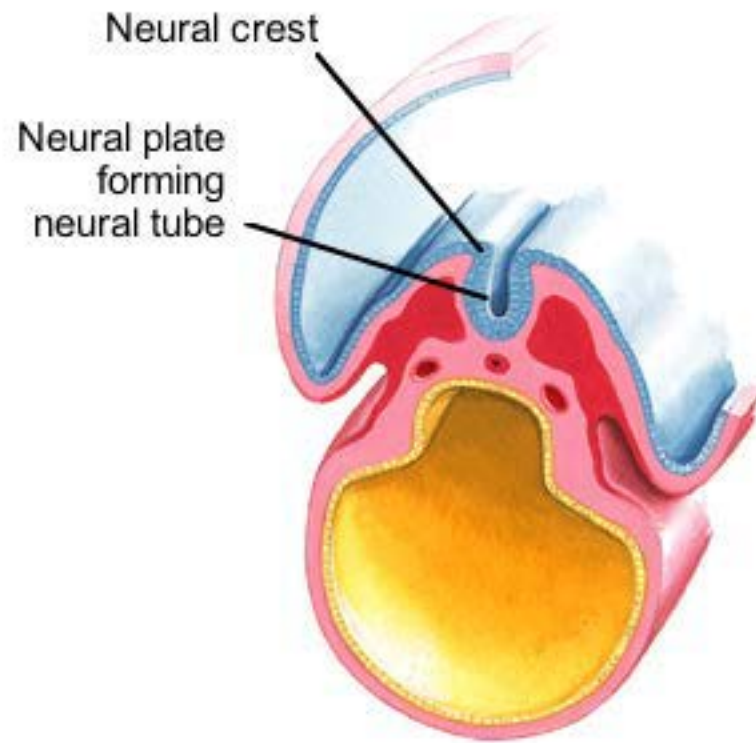


## Wall of the yolk sac

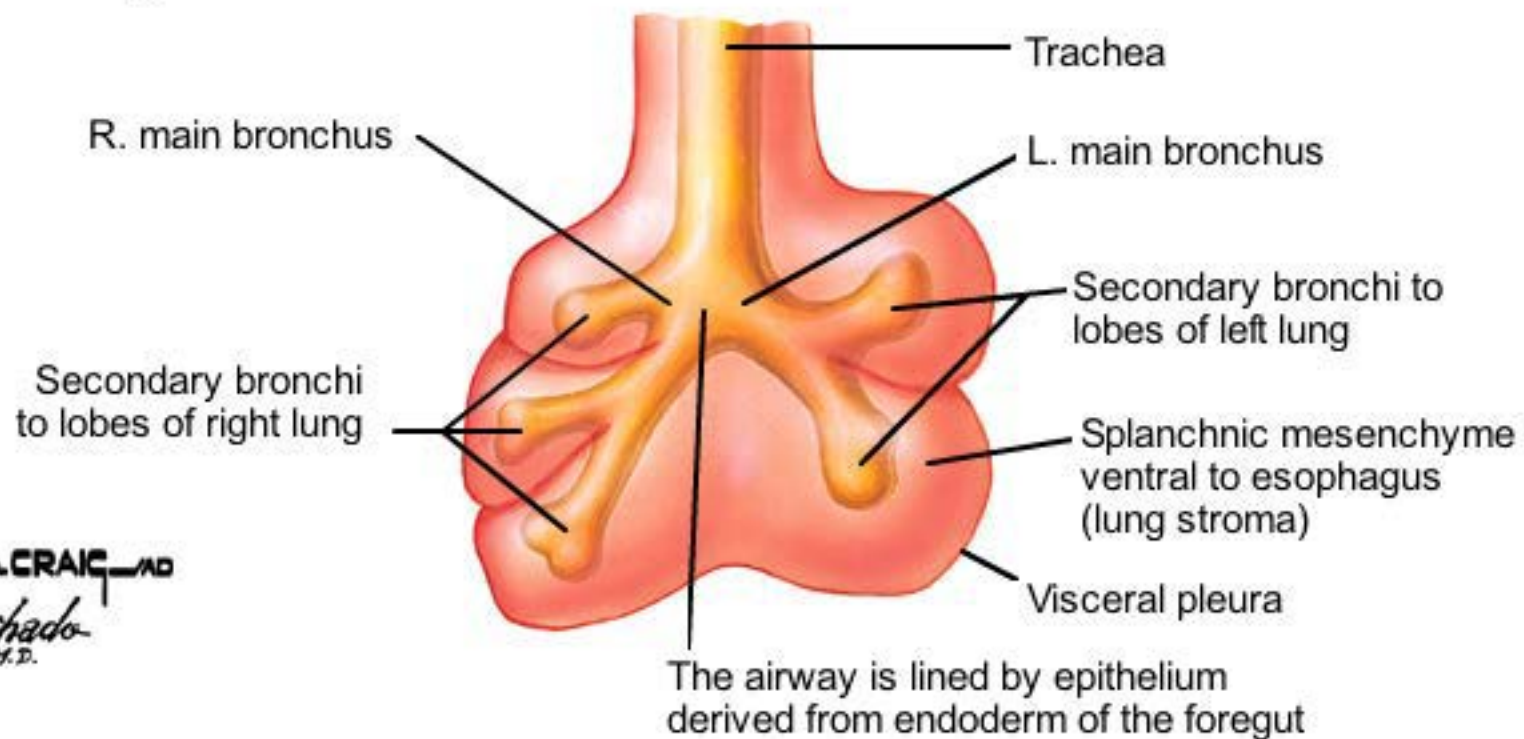




# Induction



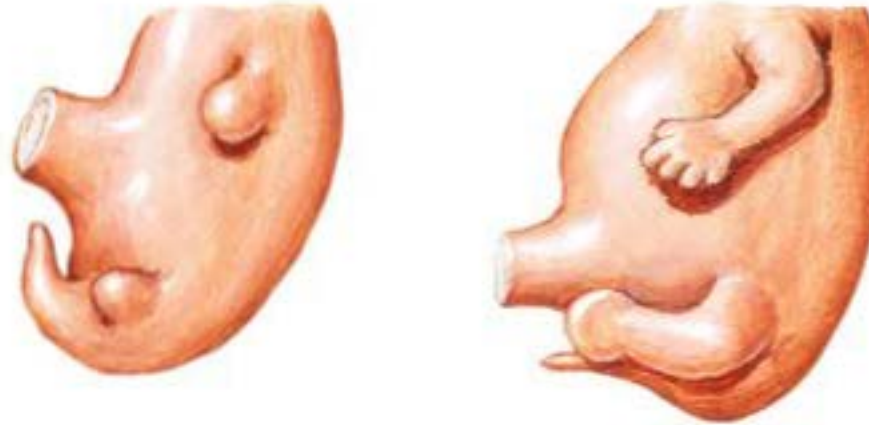
## Bronchi and lungs at 5 to 6 weeks



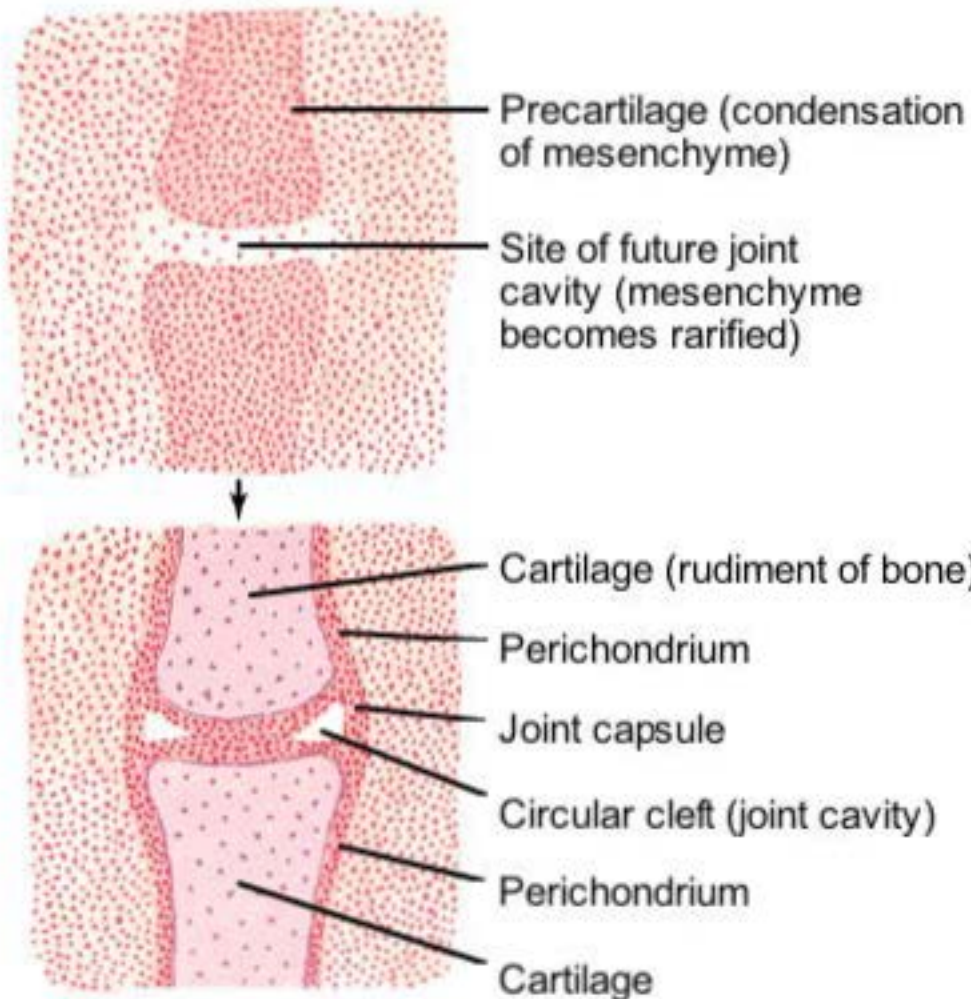


# Apoptosis

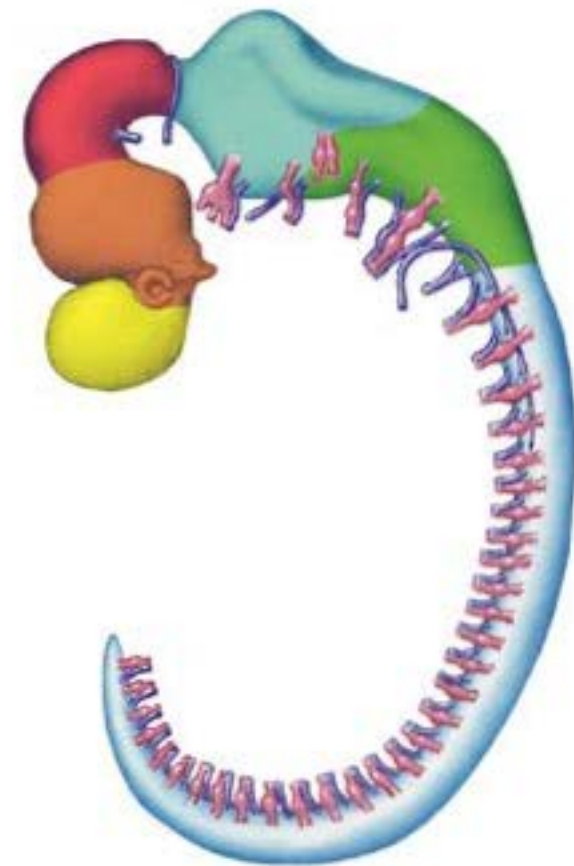
Upper and lower limb buds at 5 and 6 weeks



Formation of a joint cavity between two developing bones



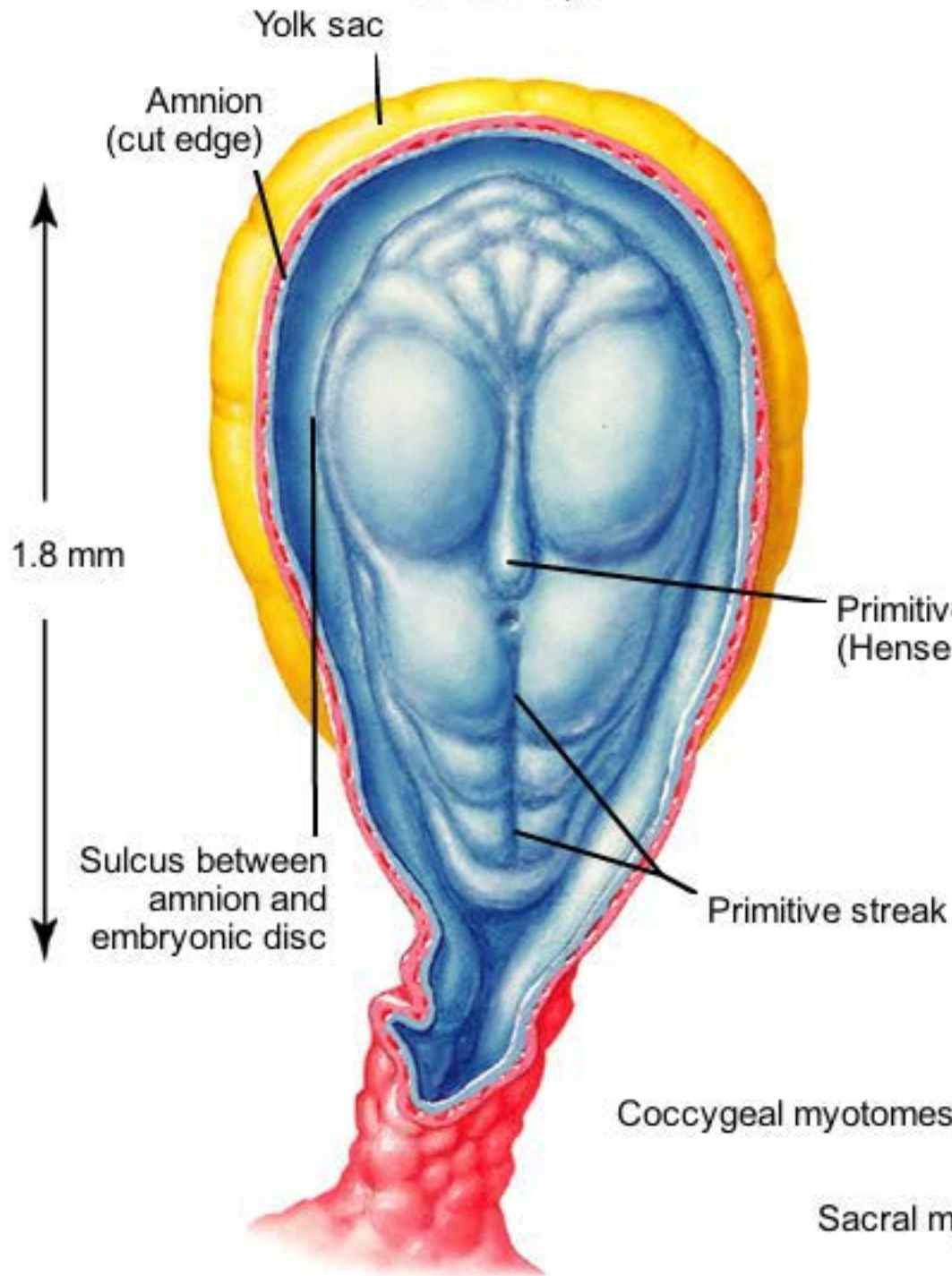
Cranial and spinal nerves at 36 days



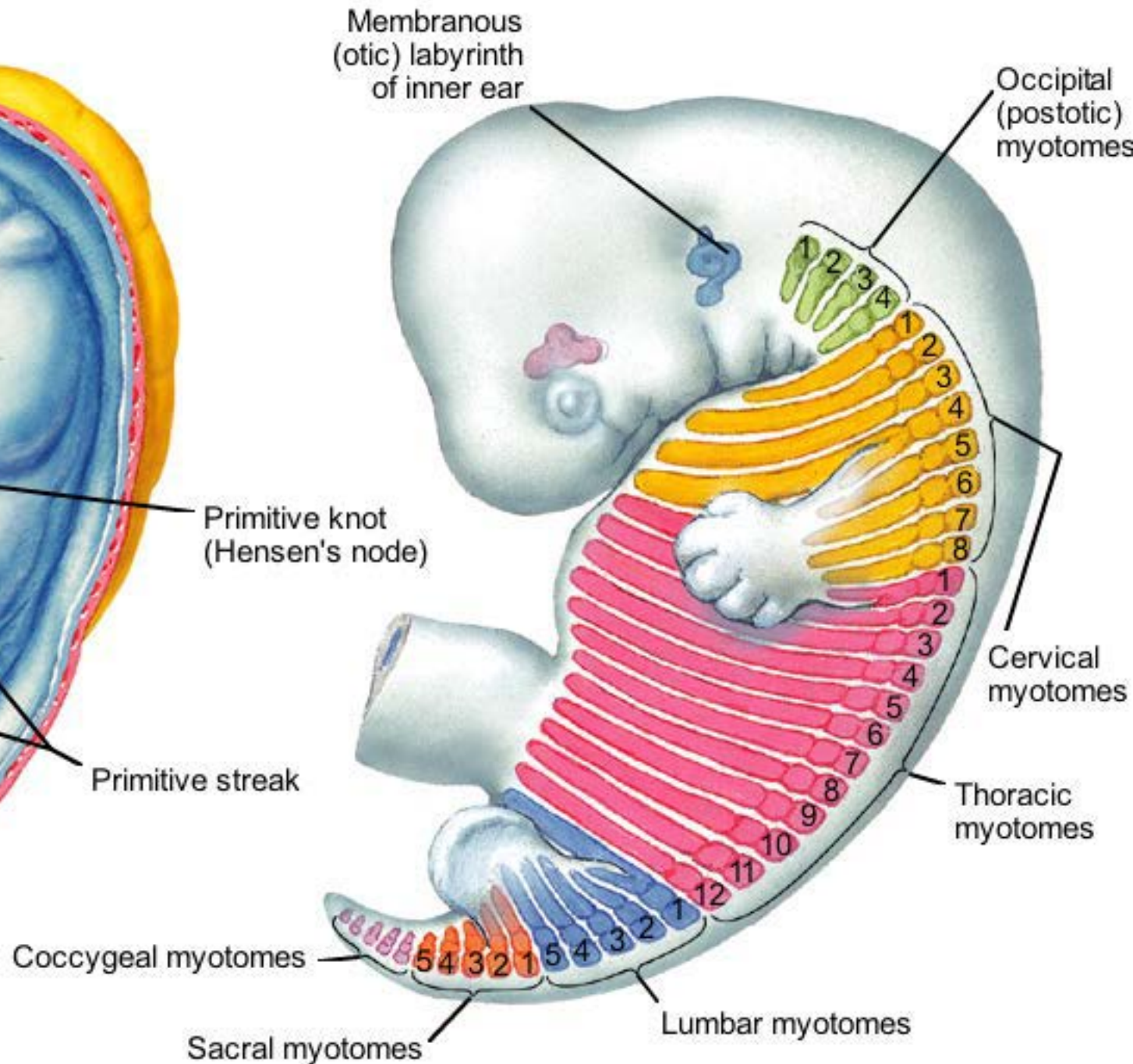


# Segmentation and Early Pattern Formation

**Dorsal view of the embryonic disc at 18 days**



**Segmental distribution of dermatomes and myotomes**

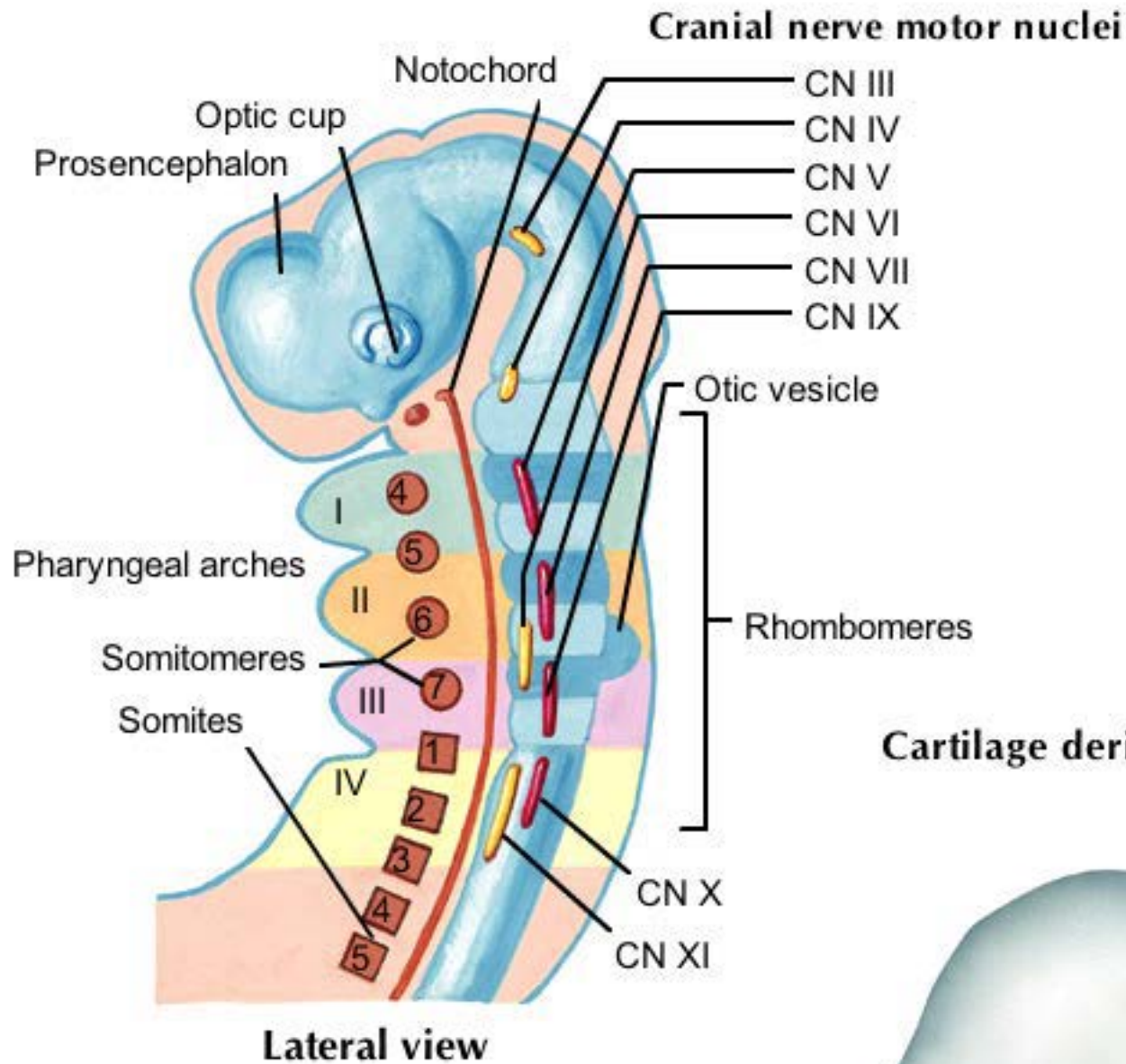


**Region of each trunk myotome also represents territory of dermatome into which motor and sensory fibers of segmental spinal nerve extend**

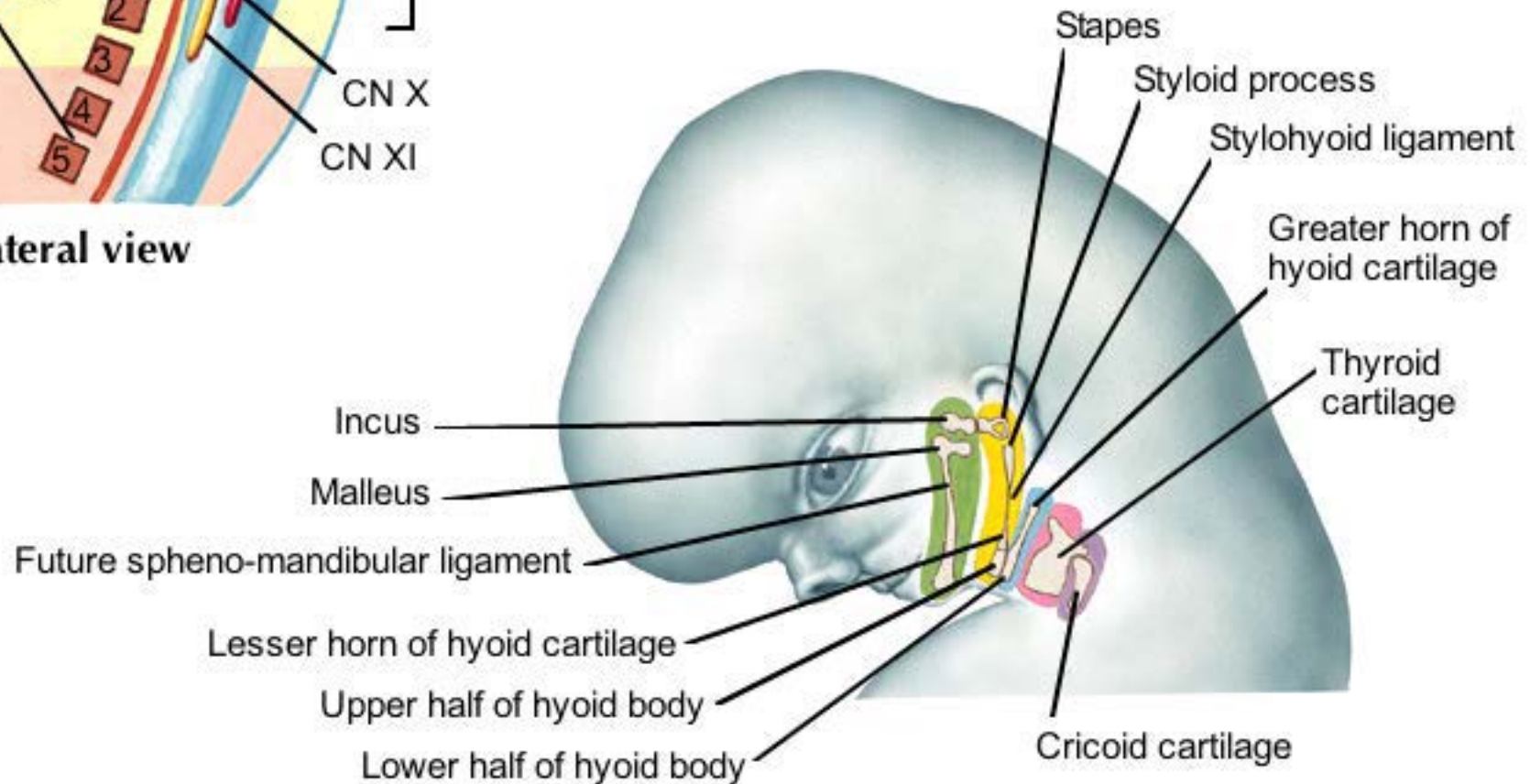


# Segmentation and Early Pattern Formation

## Segmentation in the head

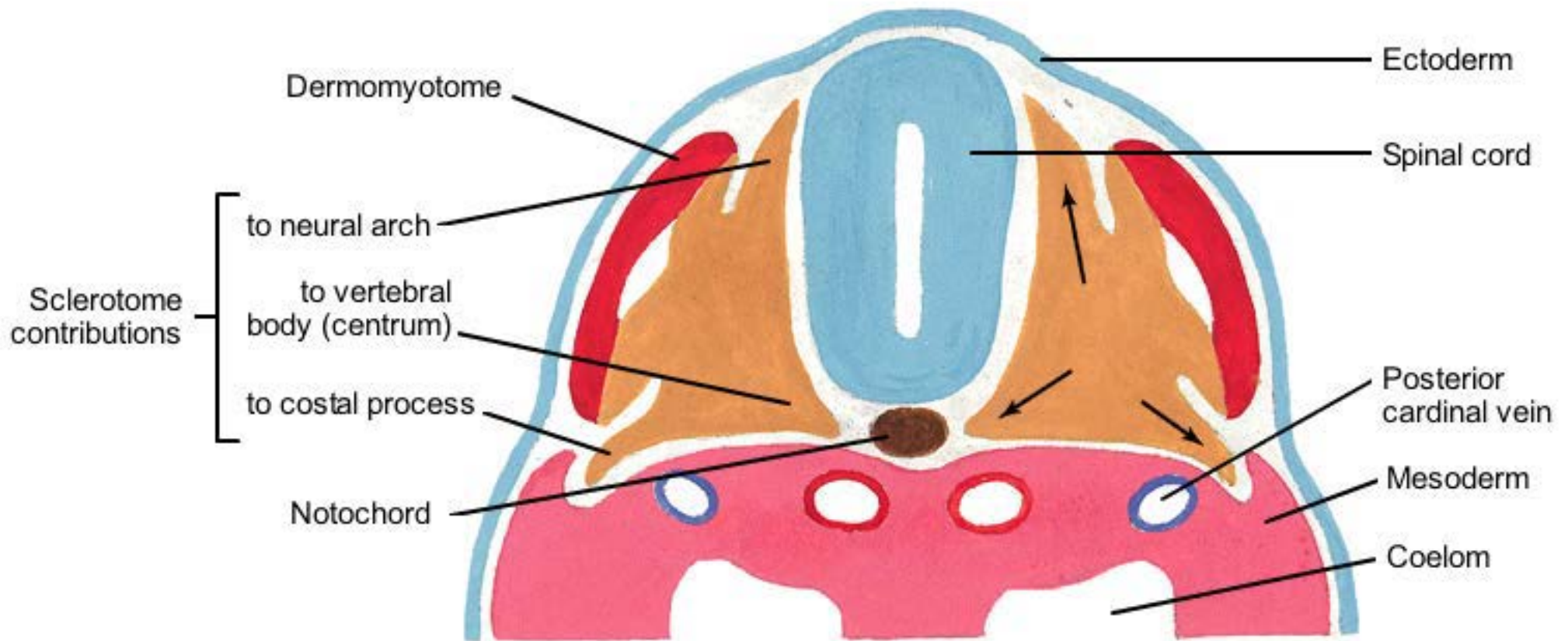


## Cartilage derivatives of the pharyngeal arches

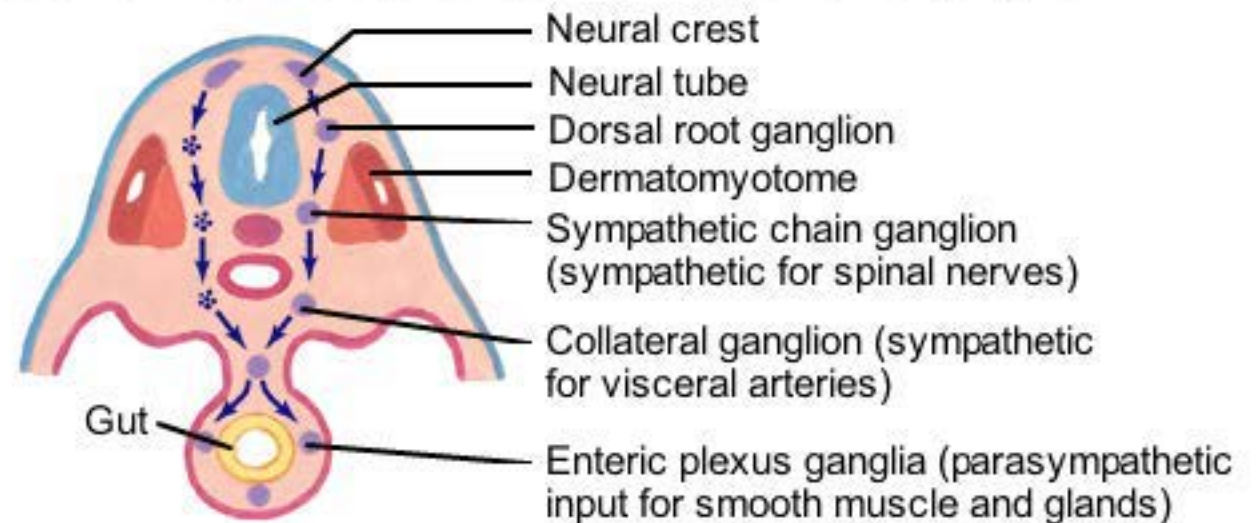


# Cell Adhesion and Cell Migration

Somite sclerotome cells dispersing to surround the neural tube in the formation of the vertebral column



## The migration of neural crest cells to form autonomic ganglia



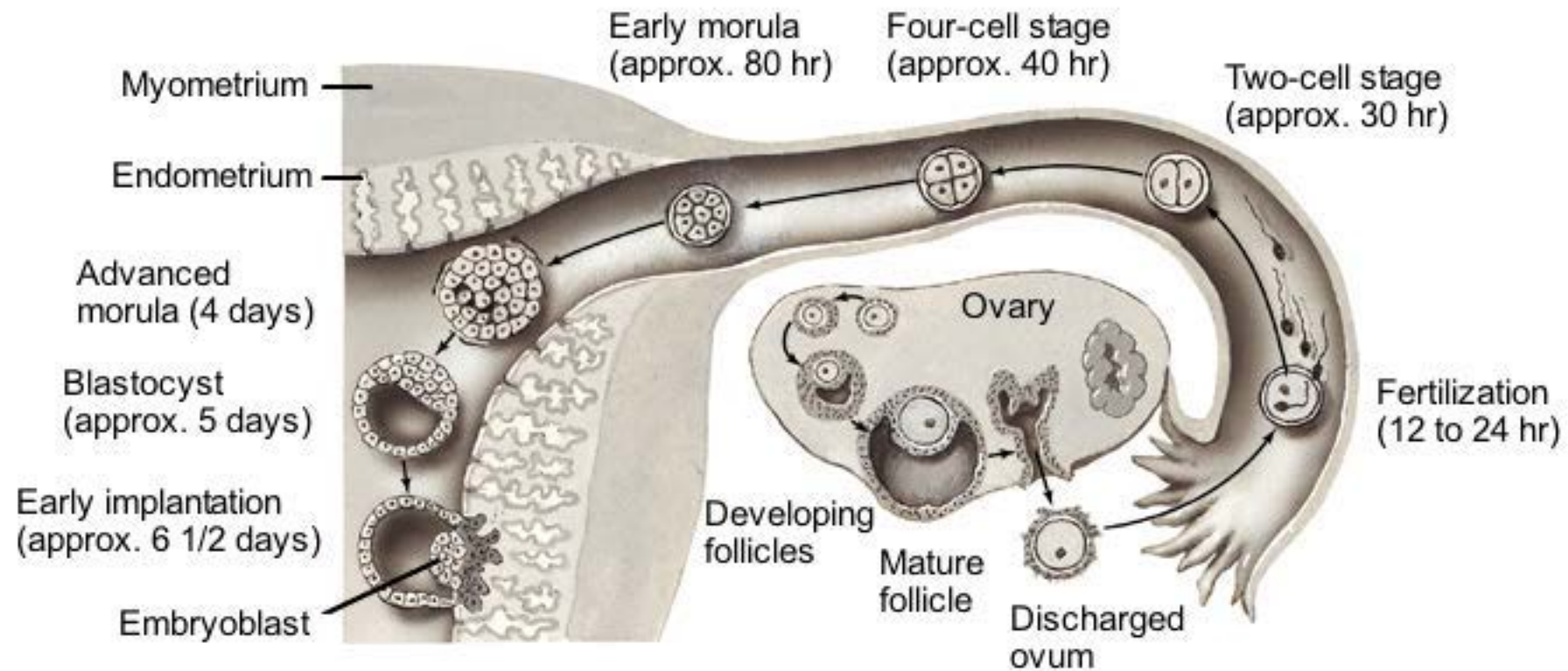
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 JOHN A. CRAIG, MD  
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Migration of neural crest cells form peripheral ganglia of autonomic nervous system

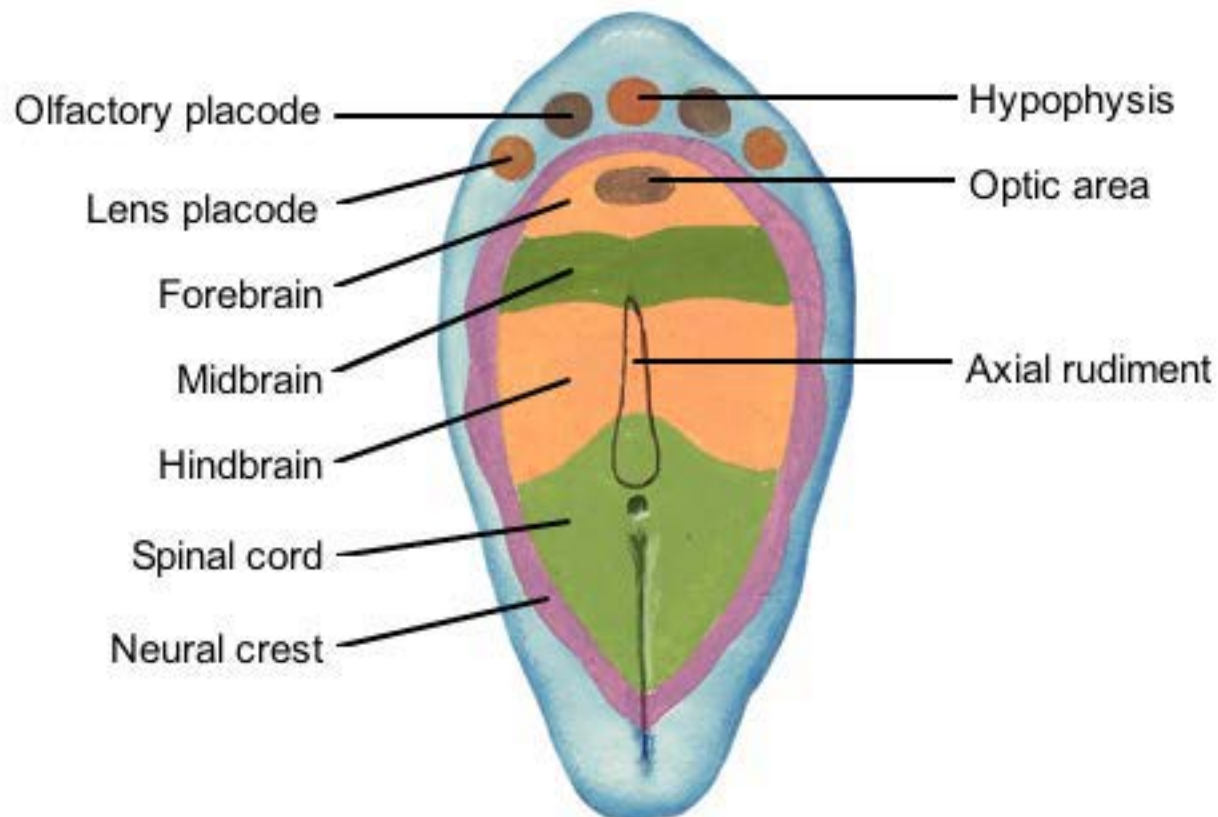


# Cell Differentiation and Cell Fates

## The first week of development

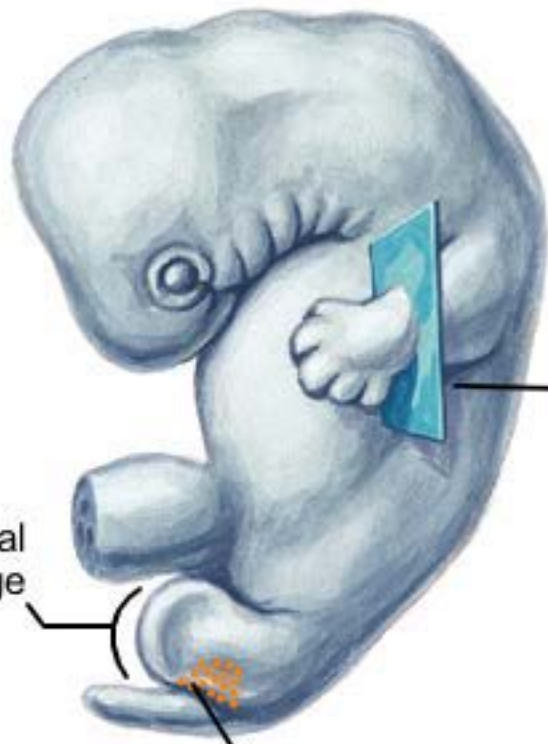


## Cellular fate map of the embryonic disc showing ectodermal contributions to the future nervous system



# Growth Factors

## Limb buds in 6-week embryo



Apical ectodermal ridge

Zone of polarizing activity

### Growth factors that influence limb morphology:

- Fibroblast growth factor-8 (FGF-8)-limb bud initiation
- Retinoic acid-limb bud initiation
- FGF-2, 4, and 8-outgrowth of the limbs
- Bone morphogenetic proteins-apoptosis of cells between digits
- Sonic hedgehog-establishment of craniocaudal limb axes
- Wnt-7a-dorsal patterning of the limbs
- En-1-ventral patterning of the limbs

Mesenchymal bone precursor

Extensor muscle

Flexor muscle

Preaxial compartment

Postaxial compartment

Ant. division nerve

Post. division nerve

Ventral compartment

Dorsal compartment

Flexor muscles

Extensor muscles

Anterior division nerves

Posterior division nerves

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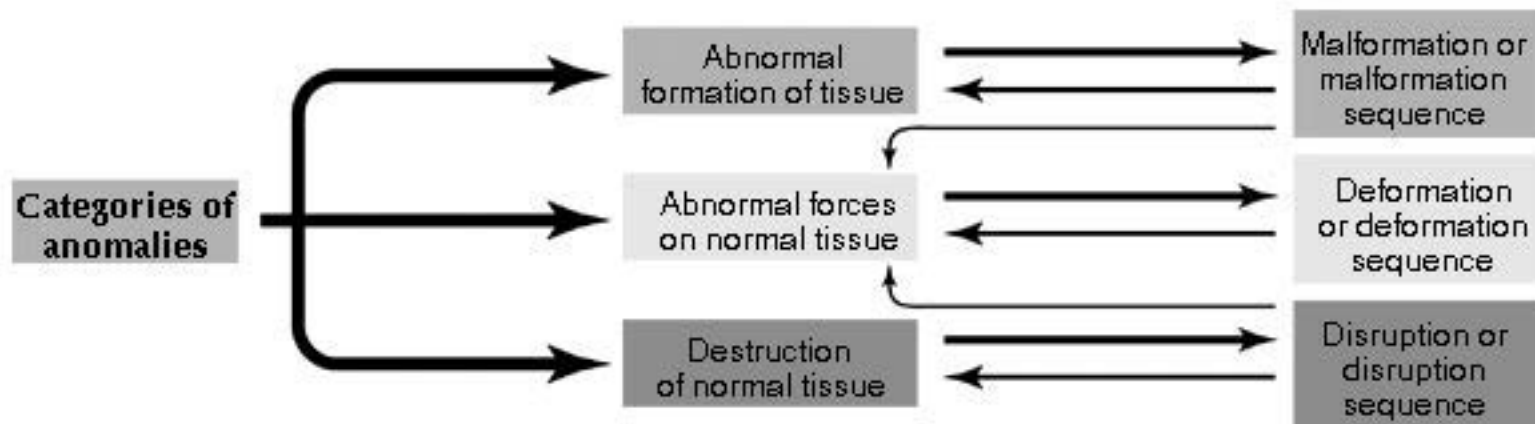
### Growth factors that promote tissue development:

- Bone morphogenetic protein family-bone development
- Indian hedgehog-bone development
- Growth/differentiation factor 5-joint formation
- Transforming growth factor- $\beta$  family-myoblast proliferation
- Nerve growth factor-sensory and sympathetic neurons
- Insulin-like growth factor-1 (IGF-1)-general proliferation of limb mesoderm
- Scatter factor (hepatic growth factor)-myotome cell migration in the limbs

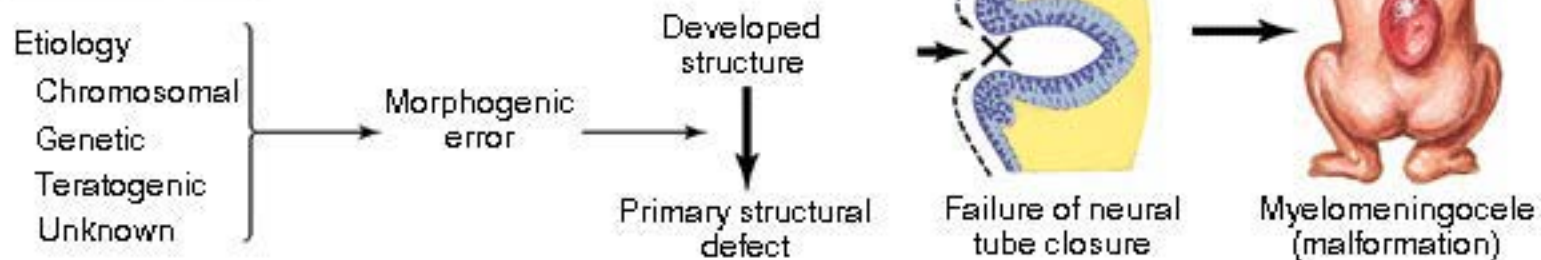


# Classification of Abnormal Processes

## The Classification of Errors of Morphogenesis

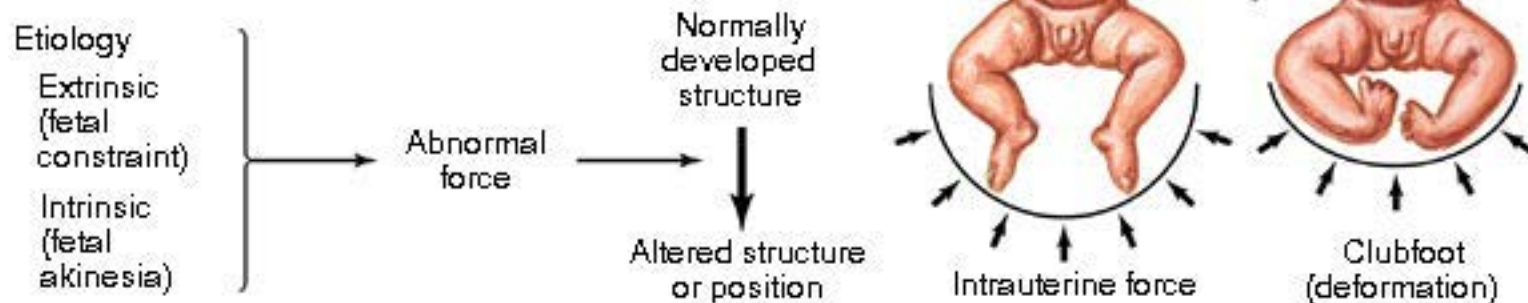


### Malformation



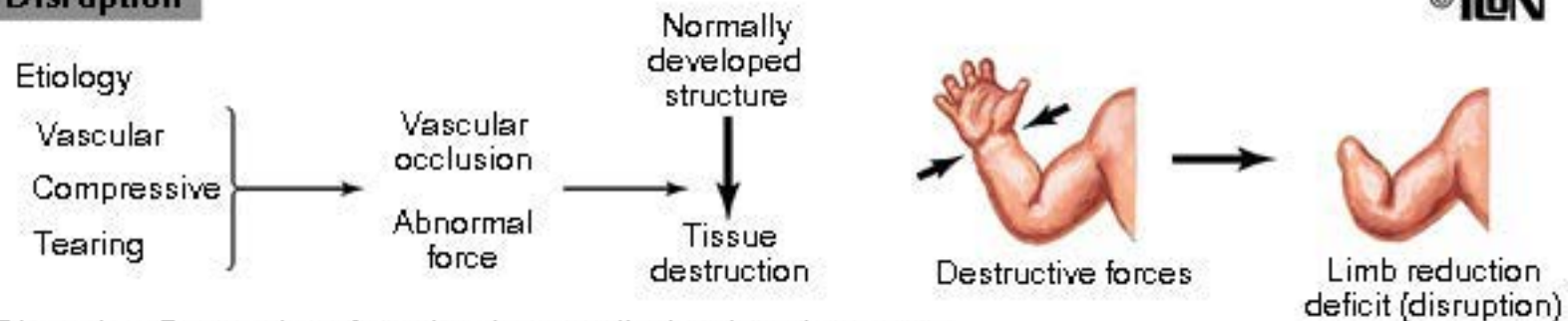
Malformation. Primary structural defect resulting from error in tissue formation

### Deformation



Deformation. Alteration in shape or position of normally developed structure

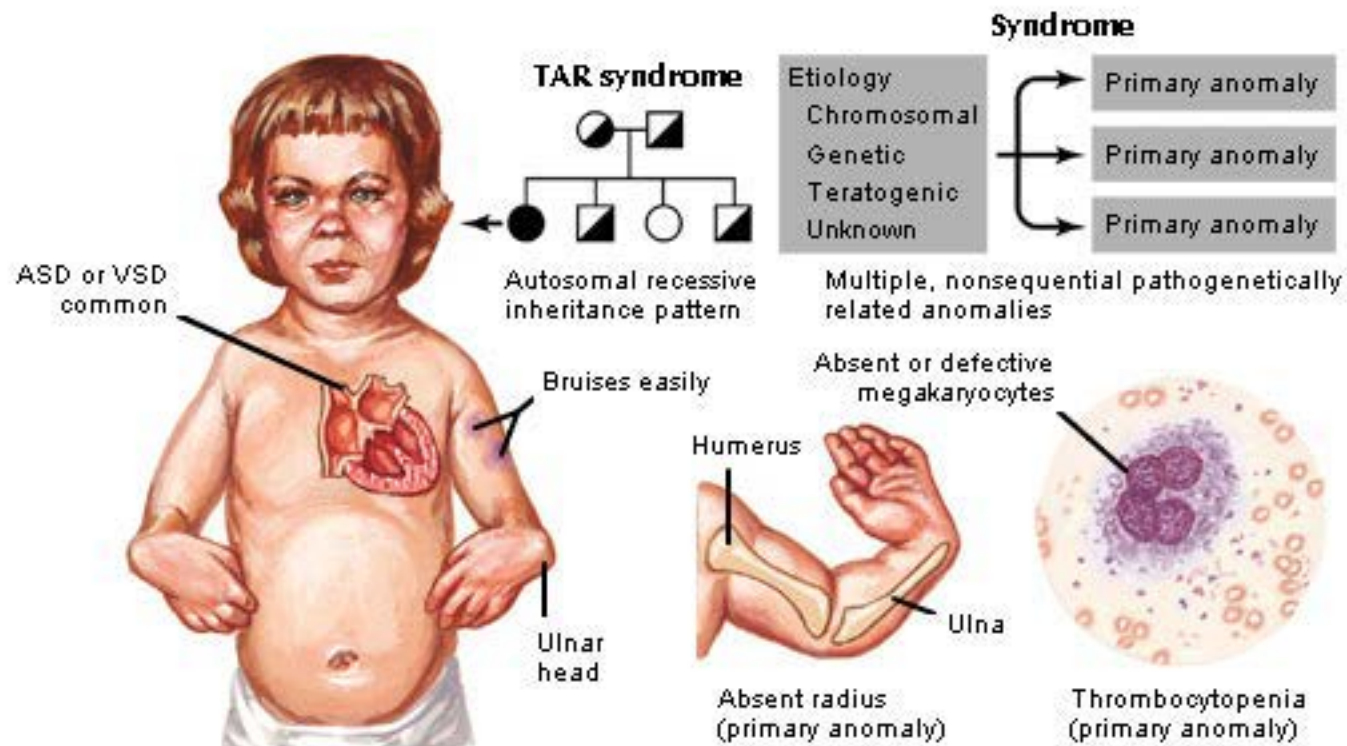
### Disruption



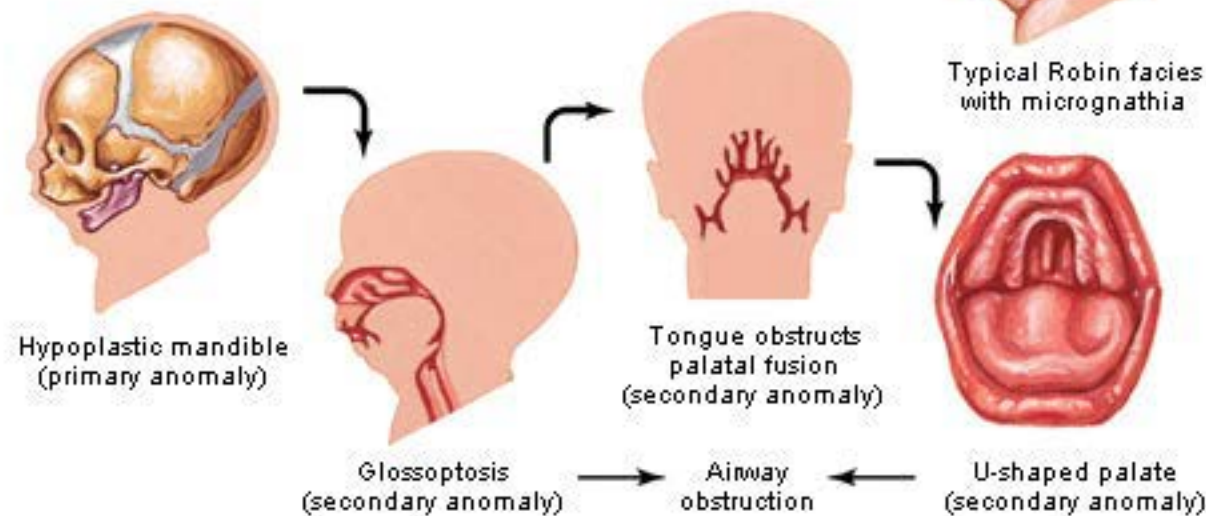
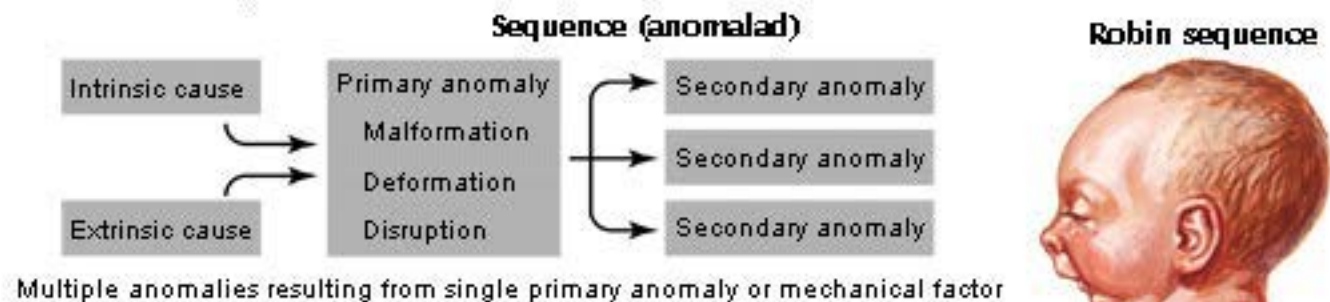
Disruption. Destruction of previously normally developed structure

# Classification of Multiple Anomalies

## Patterns of Multiple Anomalies: Syndrome Versus Sequence



TAR syndrome. Includes two anomalies: thrombocytopenia (T) and absent radius (AR). May be associated with congenital heart anomalies; autosomal recessive transmission



Sequence of anomalies initiated by hypoplastic mandible that causes glossoptosis. Resulting palatal defect with glossoptosis may obstruct airway



# Normal Versus Major Versus Minor Malformations

## The Classification of Malformations

### Normal variants



Flat nasal bridge



Hydrocele



Syndactyly of 2nd and 3rd toes

### Minor malformations



Clinodactyly of 5th finger



Simian crease



Downward slant of eyes

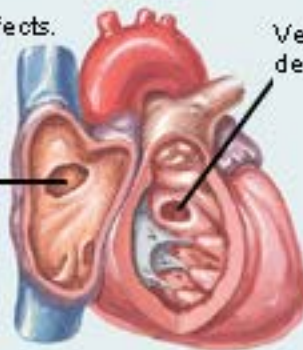
### Major malformations



Isolated cleft lip. Risk of recurrence 4%, but clefts with lip pits indicate autosomal dominant syndrome

Cardiac septal defects. Risk of recurrence 2%-5%

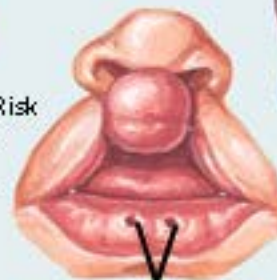
Atrial septal defect (ASD)



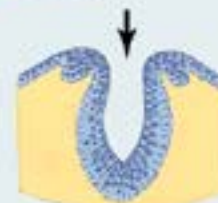
Ventricular septal defect (VSD)



Pyloric stenosis. Risk of recurrence 2%-5%



Pits



Defects in neural tube closure



Isolated aplasia cutis congenita is autosomal dominant



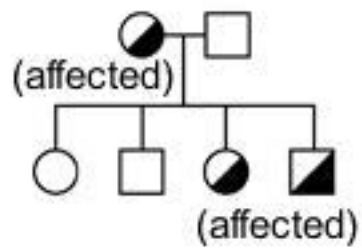
Anencephaly



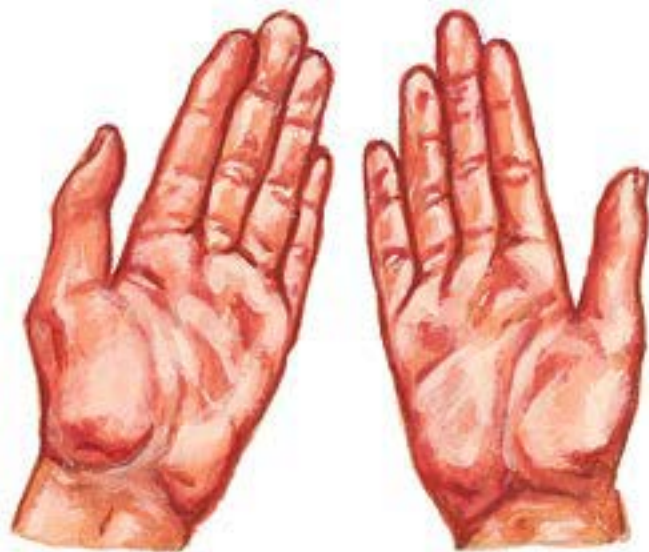
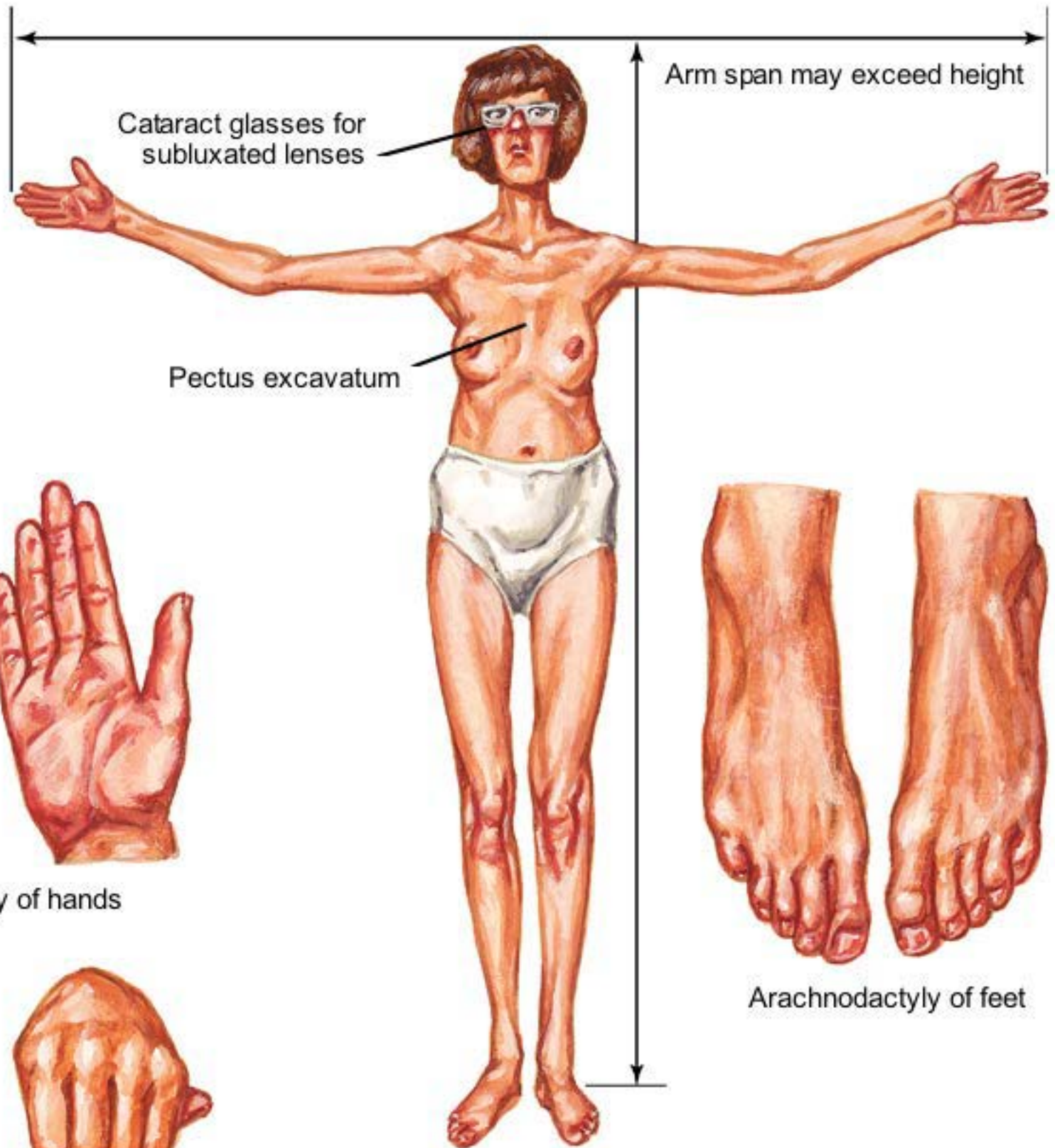
Myelomeningocele

Major and minor malformations may occur as isolated entities or as components of multiple malformation syndrome. Risk of recurrence depends on the cause of the defect

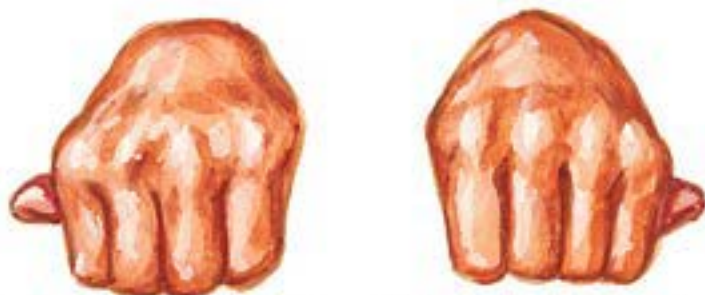
# Marfan Syndrome



Autosomal dominant inheritance pattern



Arachnodactyly of hands



**Steinberg sign.** Tip of thumb protrudes when thumb folded inside fist. Thumb and index finger overlap when encircling opposite wrist



Arachnodactyly of feet



# Apert Syndrome

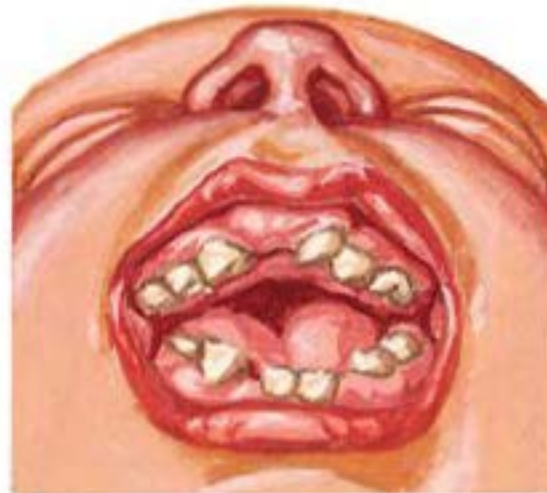


Typical facies with acrocephaly, hypertelorism, and downward slant of the eyes



Palmar "spoon" deformity

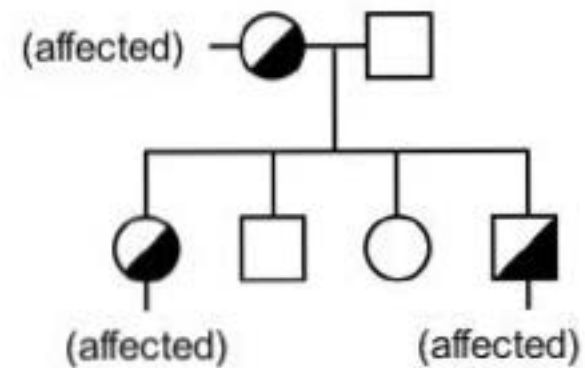
Dorsal "mitten" deformity



High-arched palate and dental anomalies



Acrocephaly with flattened midface

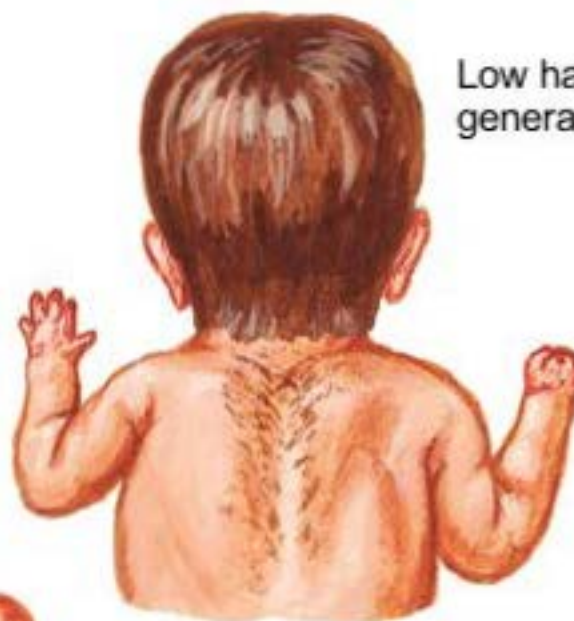


Autosomal dominant inheritance pattern

# De Lange Syndrome



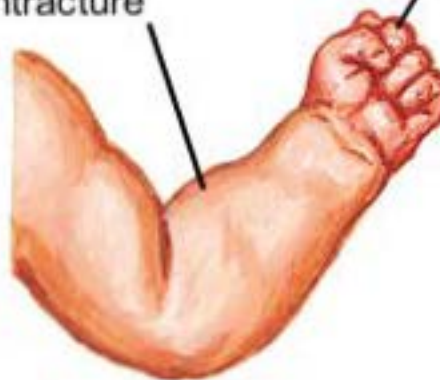
Infant facies with thick, conjoined eyebrows (synophrys) and thin lips



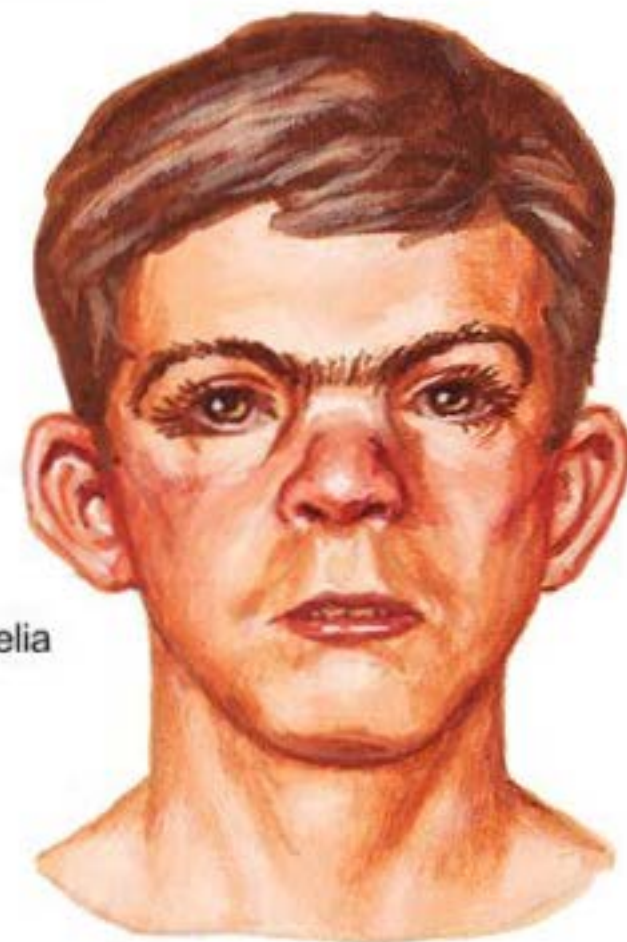
Low hairline and general hirsutism

Phocomelia

Flexion contracture



Micromelia



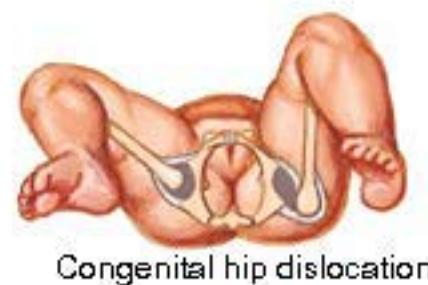
Adult facies with synophrys and long eyelashes



# Examples of Deformations



Uterine malformation

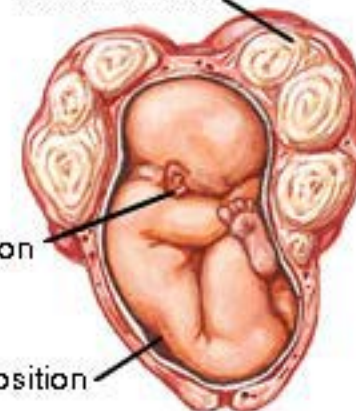


Uterine fibroid



Ear distortion

Breech position



Uterine pathology



Limb position anomalies

Conditions that cause intrauterine crowding can lead to abnormal fetal positions and thus cause constraint deformities



Primigravida (small uterine cavity)

Multigravida (large uterine cavity)



At birth



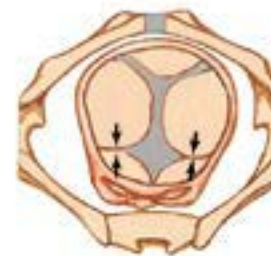
Constraint-related growth deficiency is transient. Given room, small infants catch up rapidly



Scaphocephaly due to sagittal craniosynostosis



Limitation of growth of sagittal suture



Limitation of growth of coronal sutures



Brachycephaly due to coronal craniosynostosis

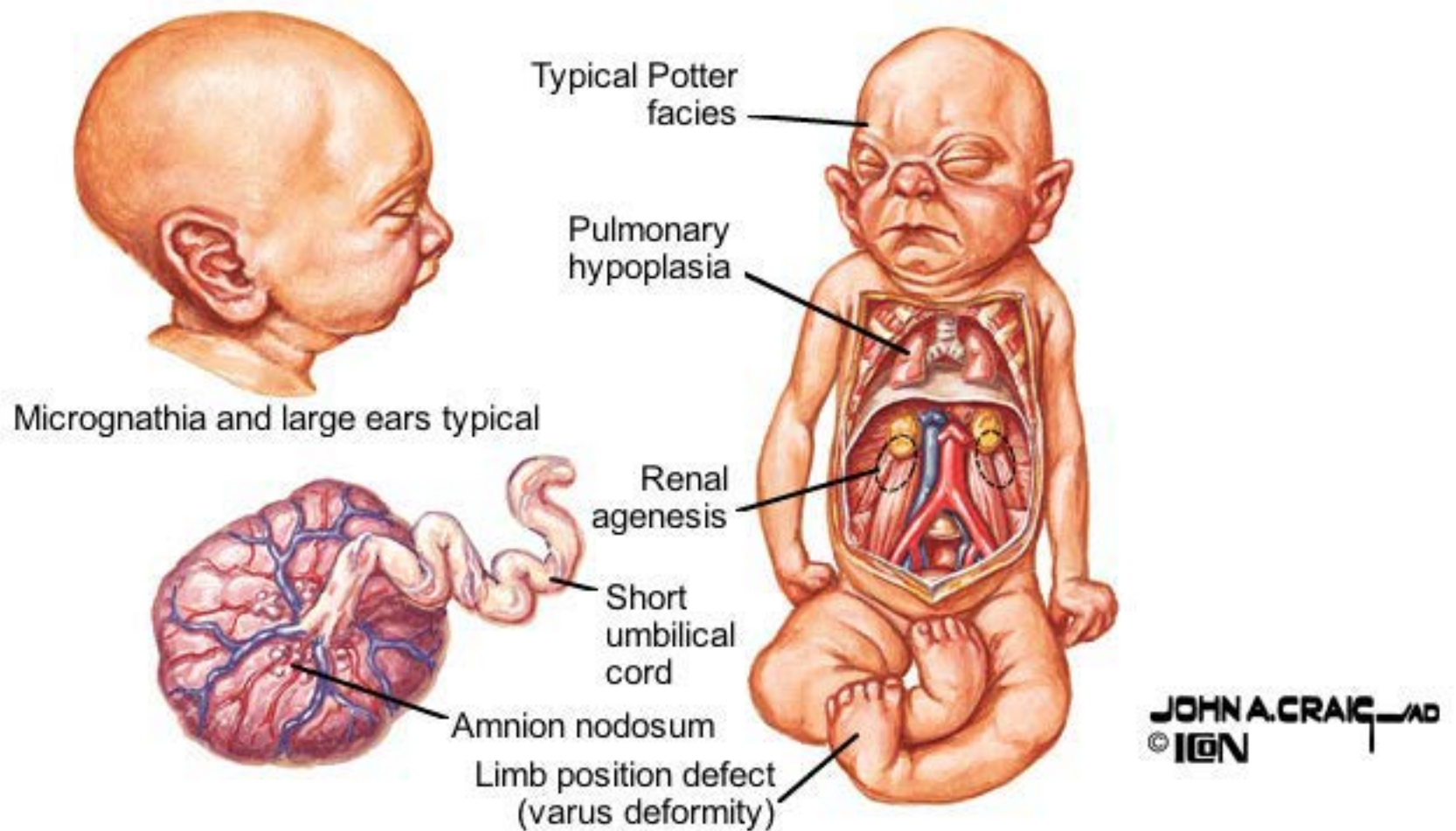
Early engagement of fetal head may limit sutural growth and result in craniosynostotic skull deformities

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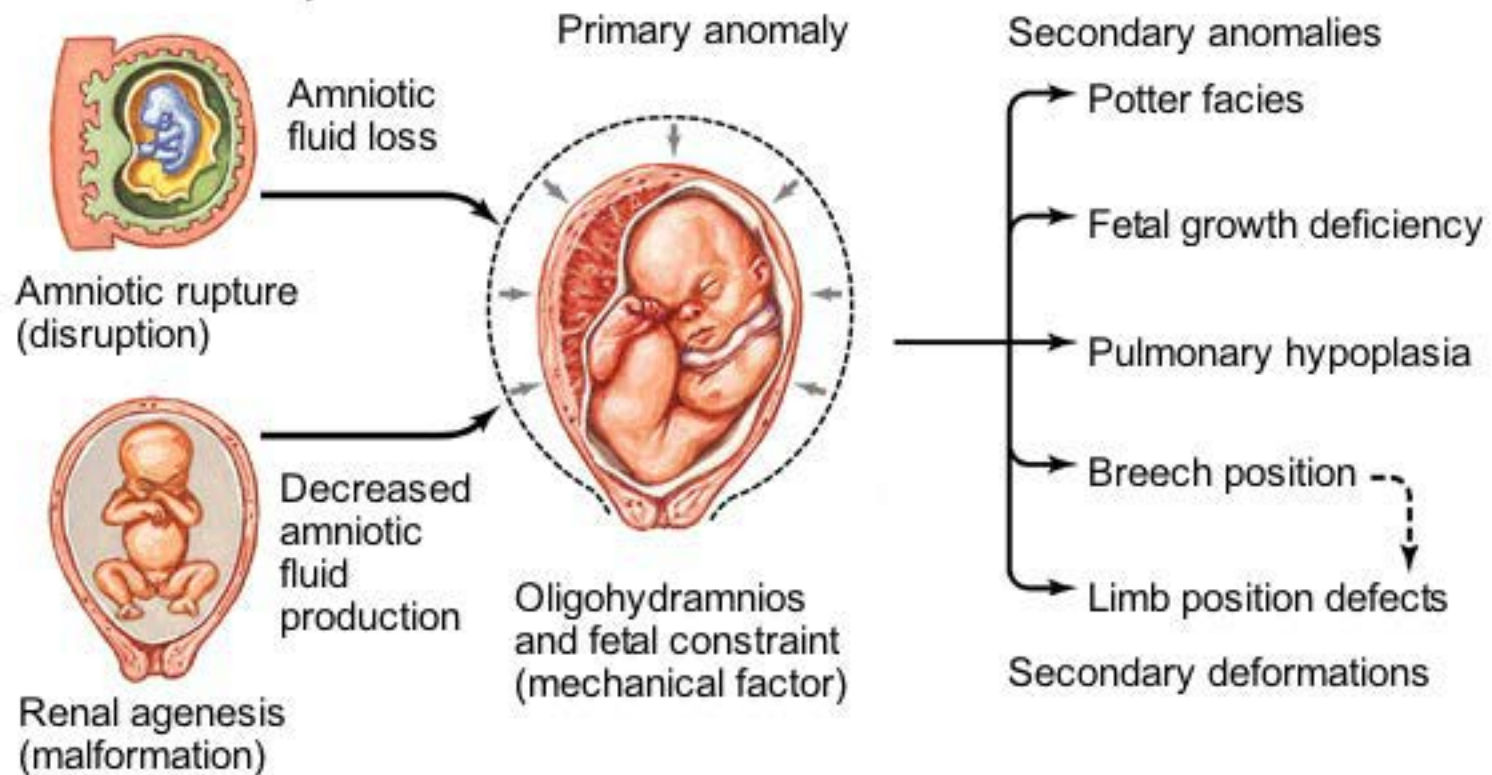


# Example of a Deformation Sequence

## Potter Sequence



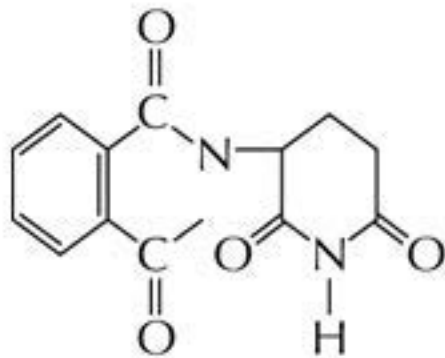
### Events in Potter sequence





# Drug-Induced Embryopathies

## Thalidomide



( $\alpha$ [N-phthalimido]glutarimide)



27- to 33-day embryo

Midline  
hemangioma



Flat nasal bridge

Phocomelia



Clinical features of  
thalidomide embryopathy



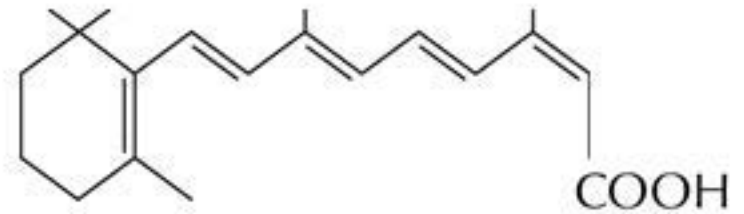
Limb defects. From hypoplasia to complete  
absence of radius, ulna, and humerus;  
fibula and tibia less commonly involved

# Drug-Induced Embryopathies

## Retinoic acid



Facial features. Ocular hypertelorism with down-slanting palpebral fissures, micrognathia, and U-shaped palate



(13-*cis*-retinoic acid)

Anterolateral displacement of hair whorl

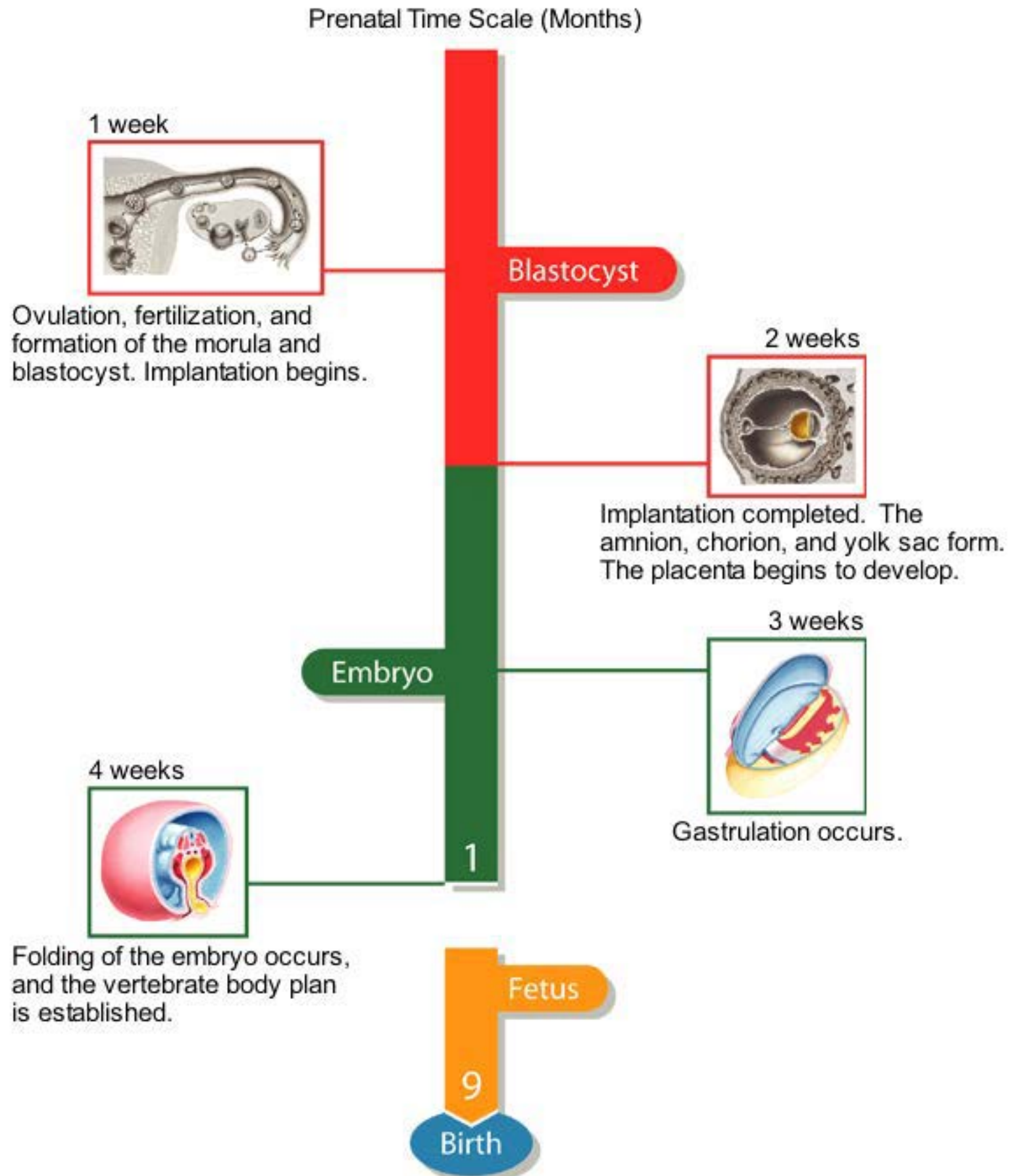
Microtia or anotia, with or without stenosis of external canal



Hydrocephalus may occur

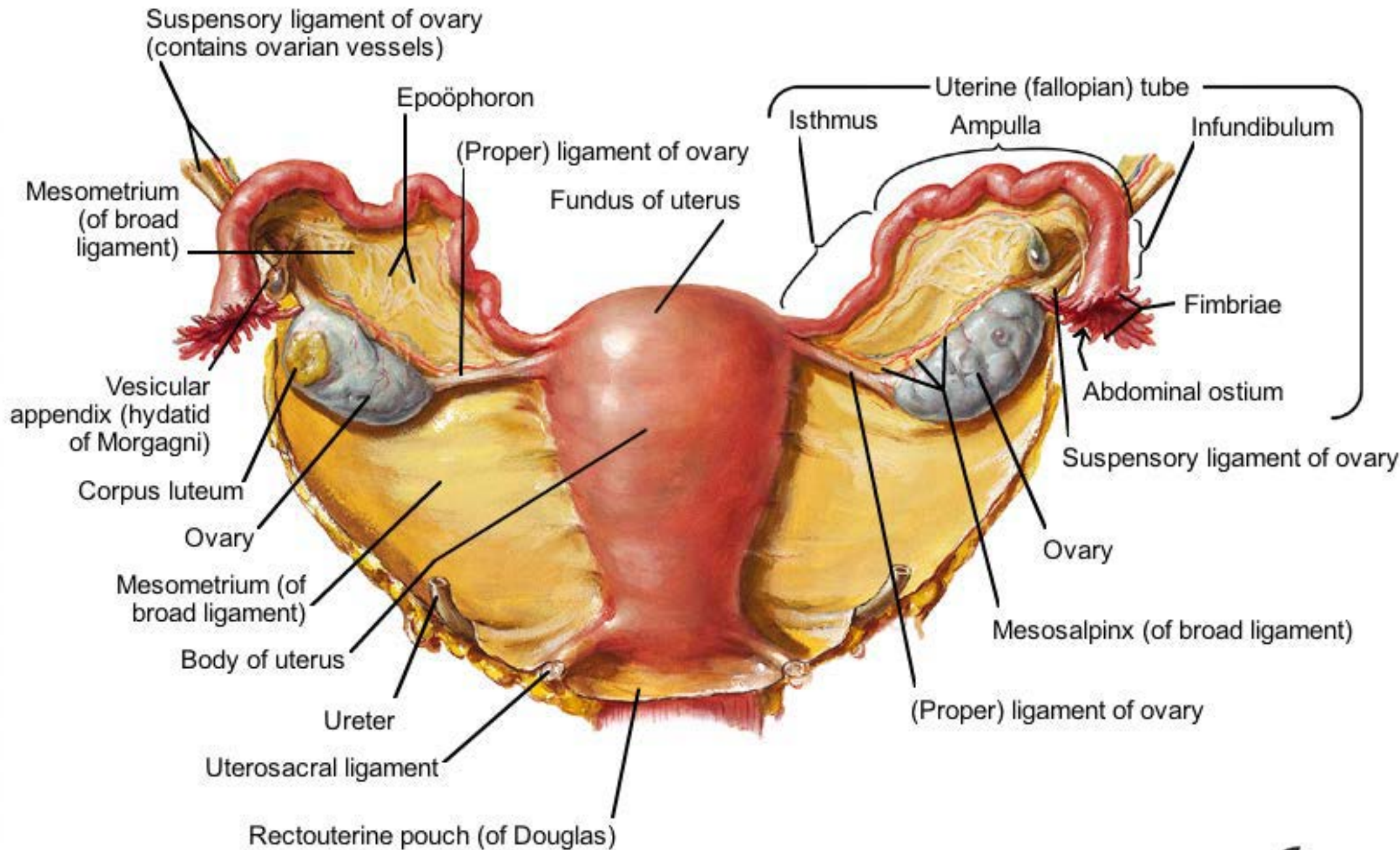


# EARLY EMBRYONIC DEVELOPMENT AND THE PLACENTA TIMELINE



# Adult Uterus, Ovaries, and Uterine Tubes

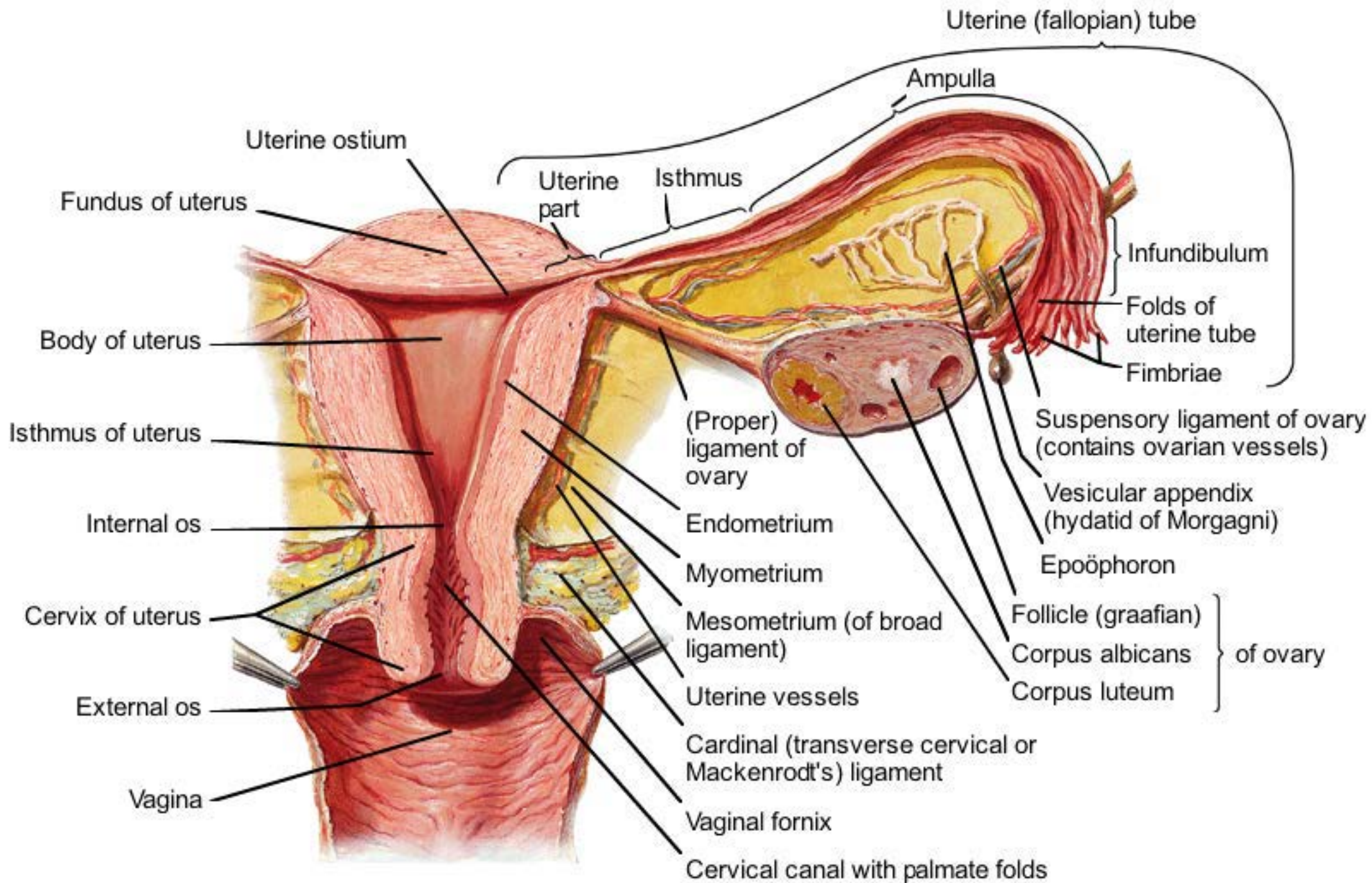
## Posterior view





# Adult Uterus, Ovaries, and Uterine Tubes

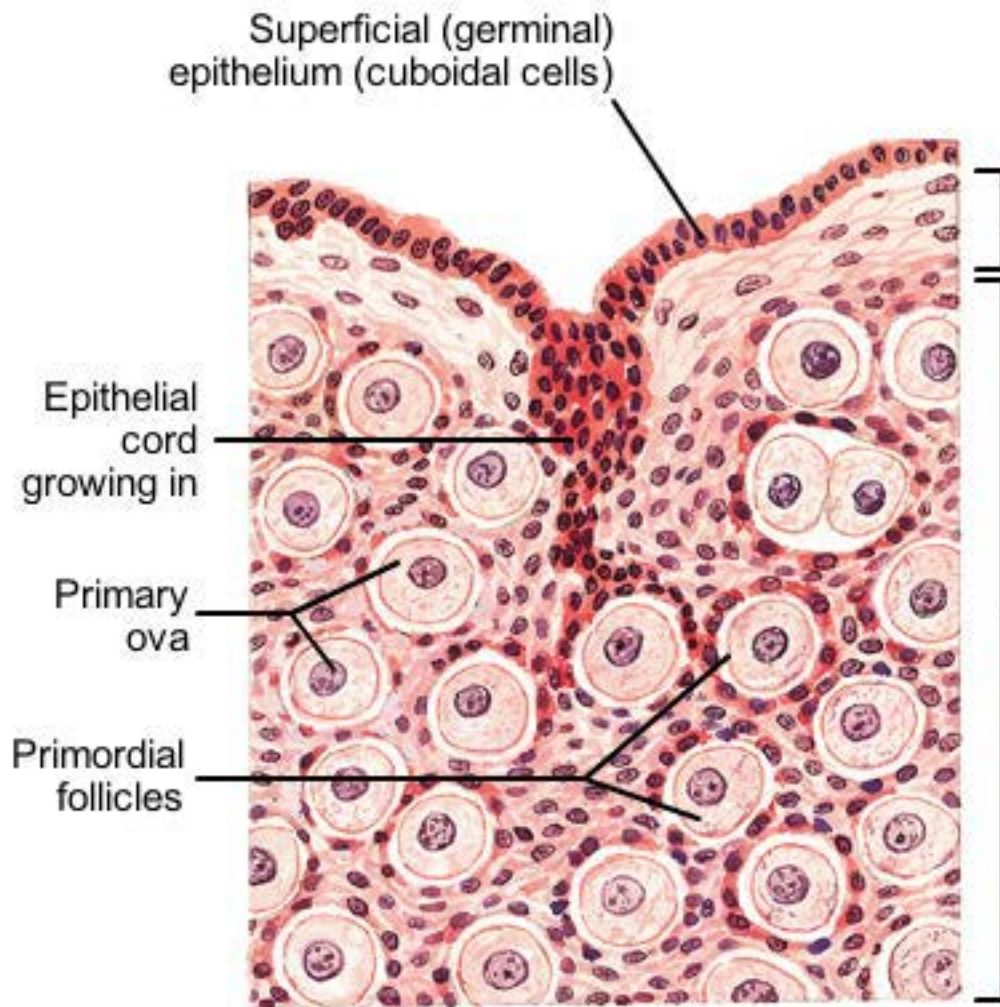
## Frontal section



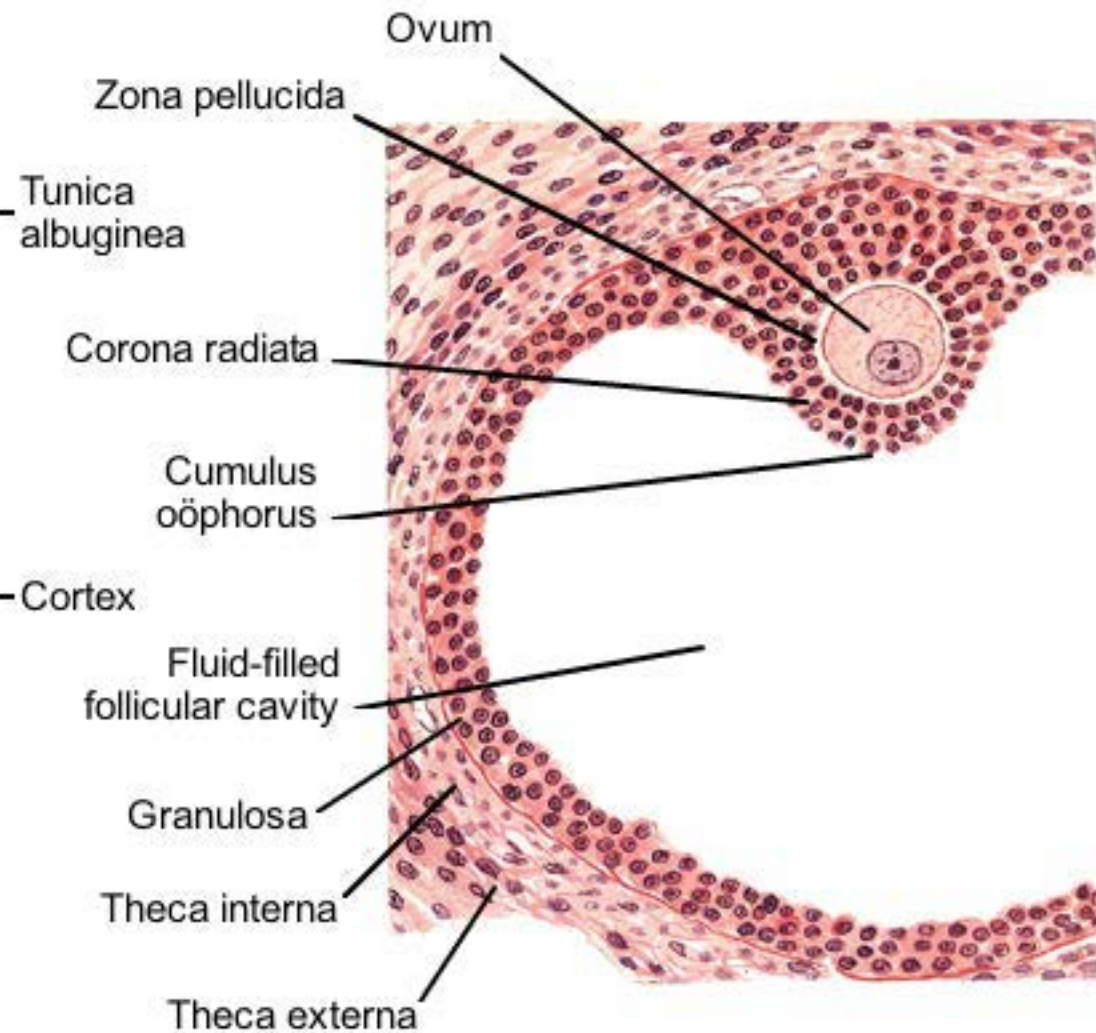


# Ovary, Ova, and Follicle Development

Infant ovary



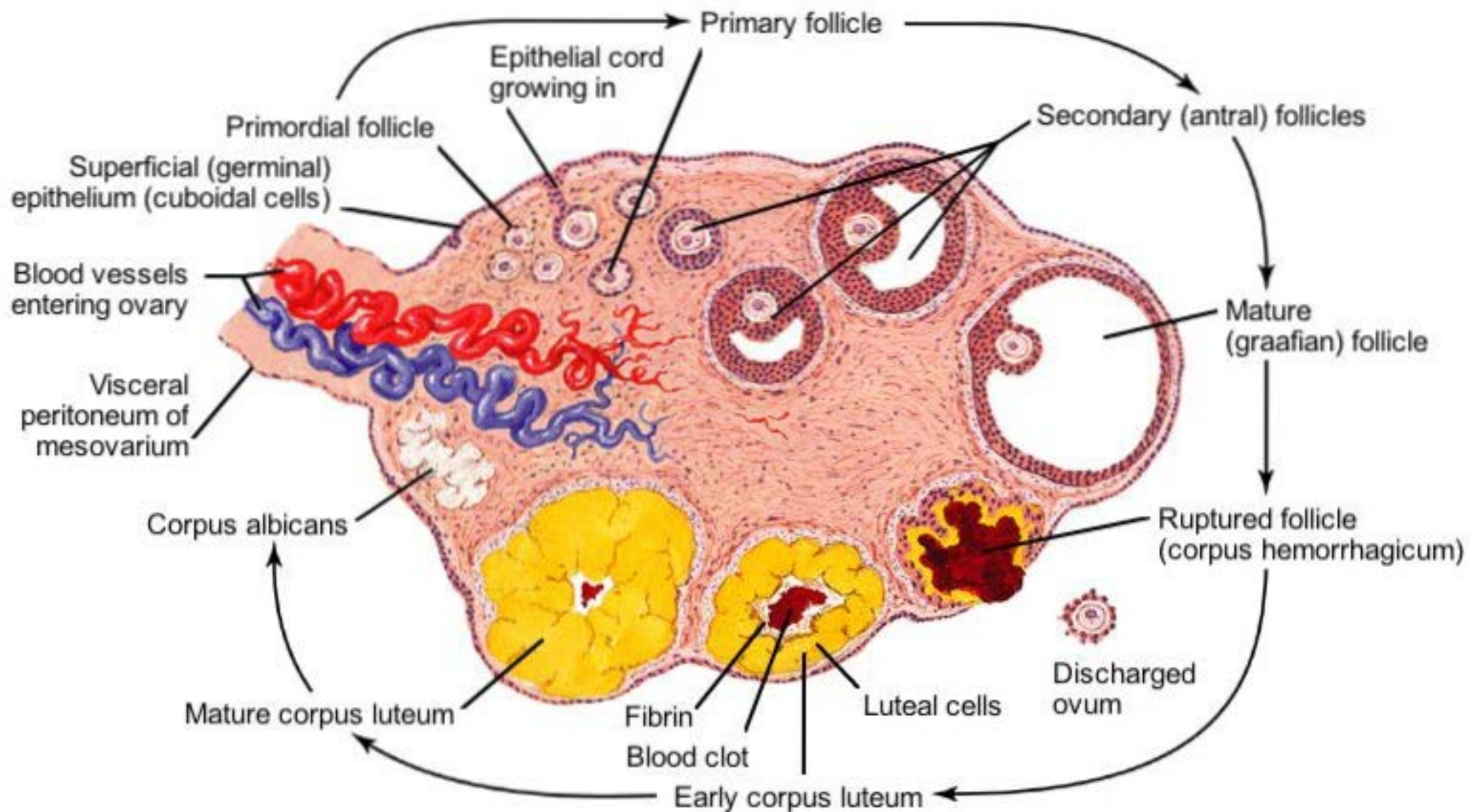
Developing follicle





# Ovary, Ova, and Follicle Development

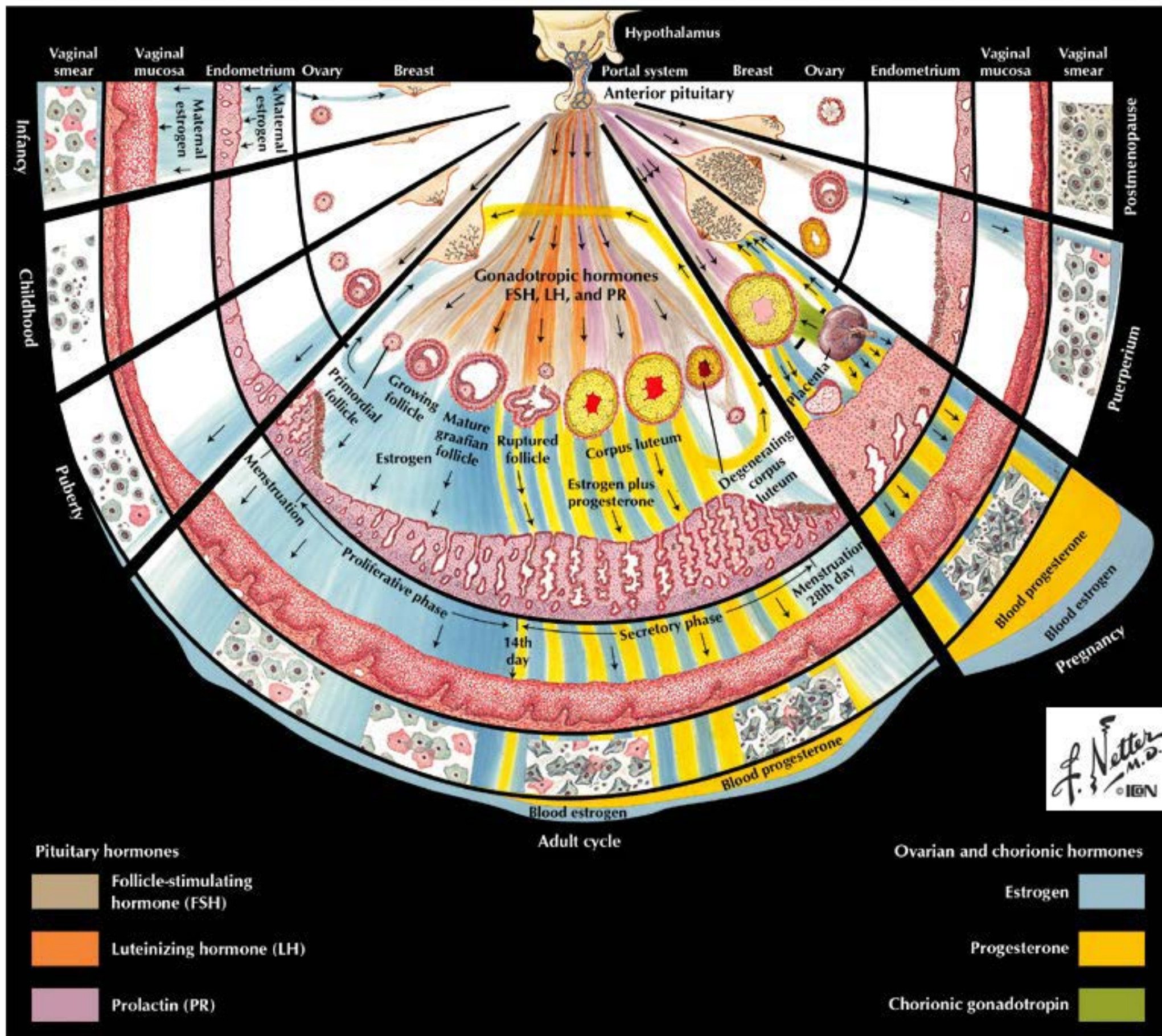
## Stages of ovum and follicle





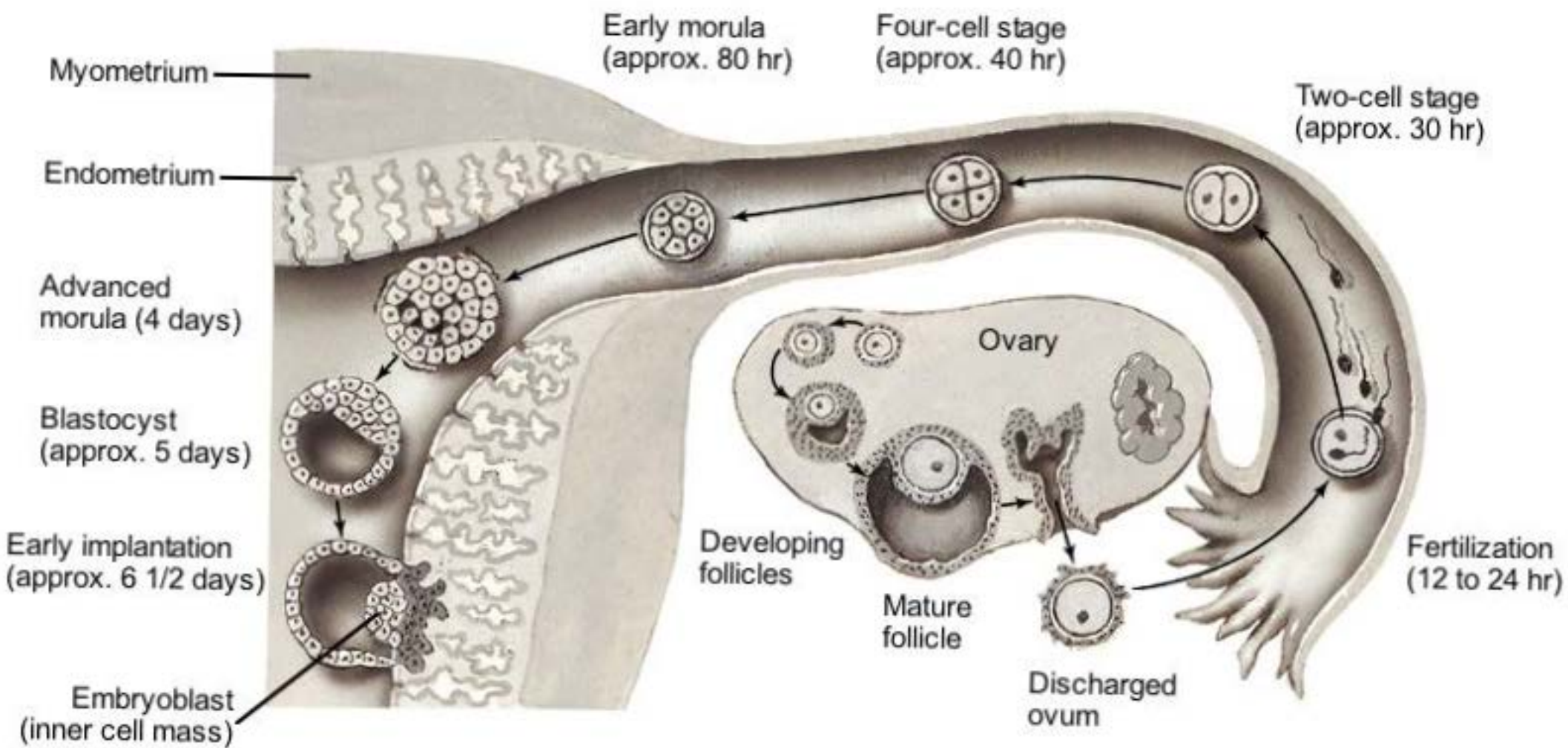
# The Menstrual Cycle and Pregnancy

## Regulation of follicle and endometrial development and pregnancy



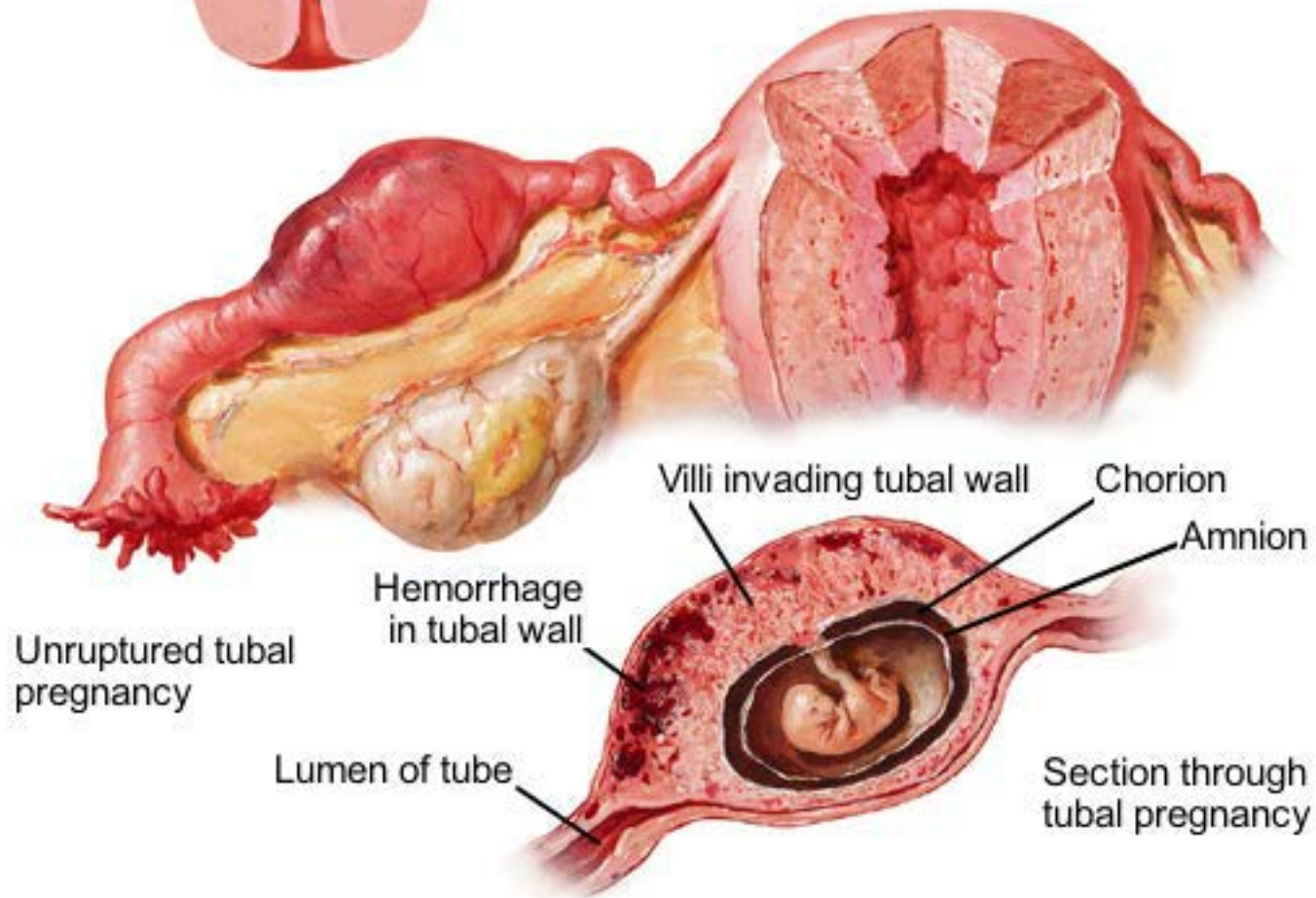
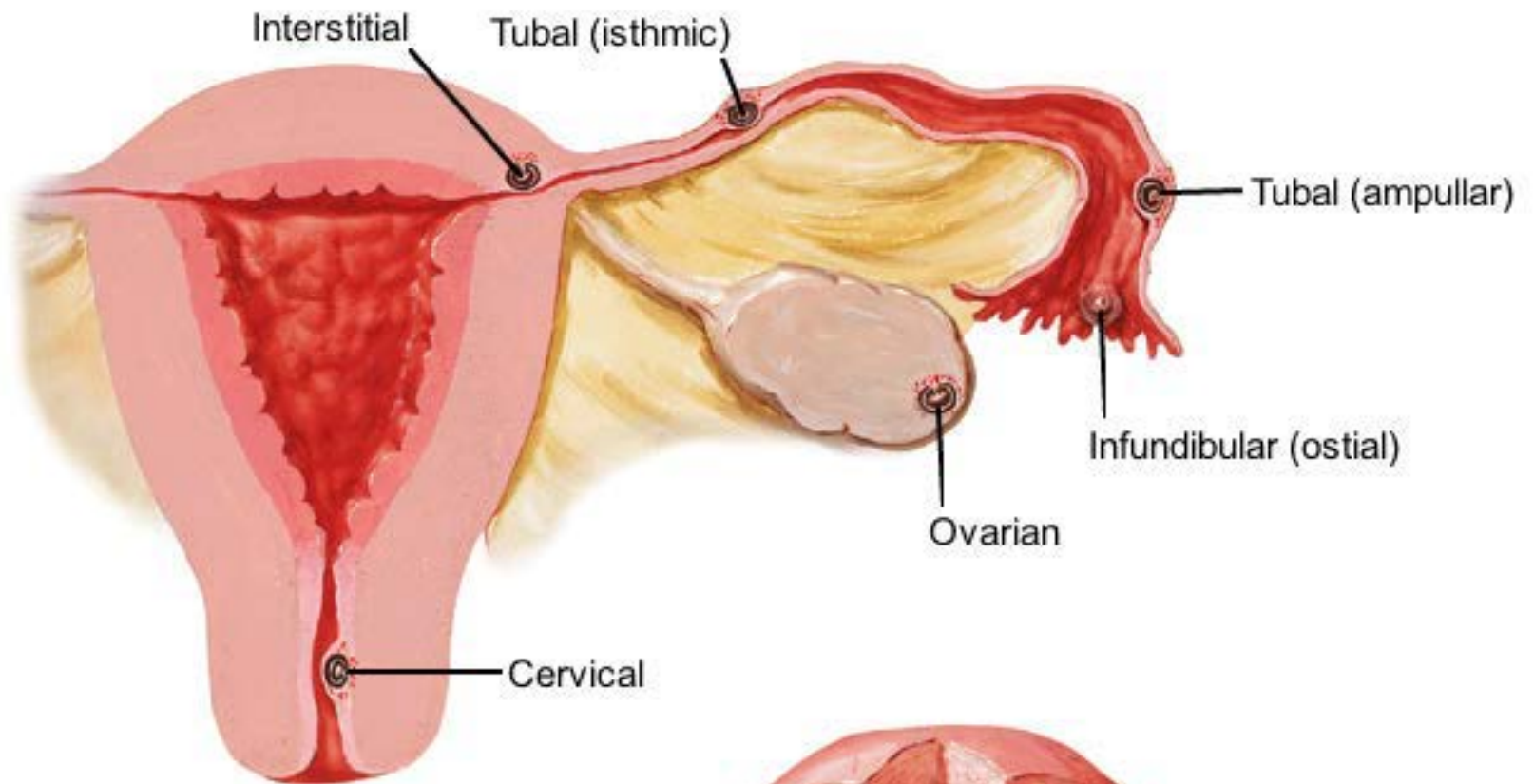


# The First Week



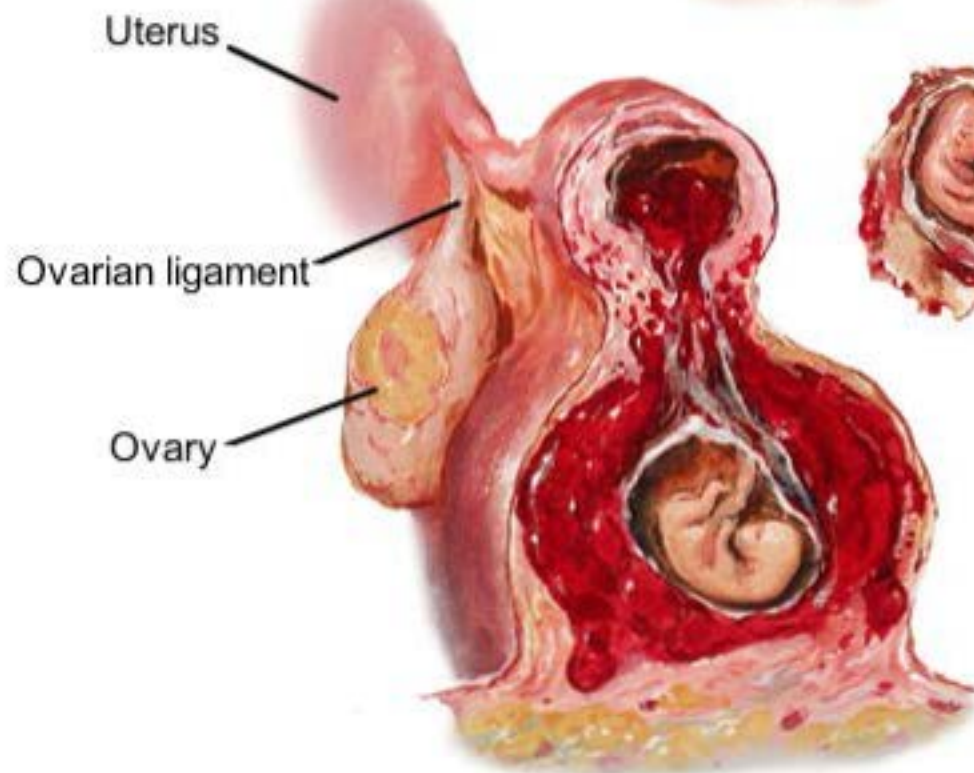
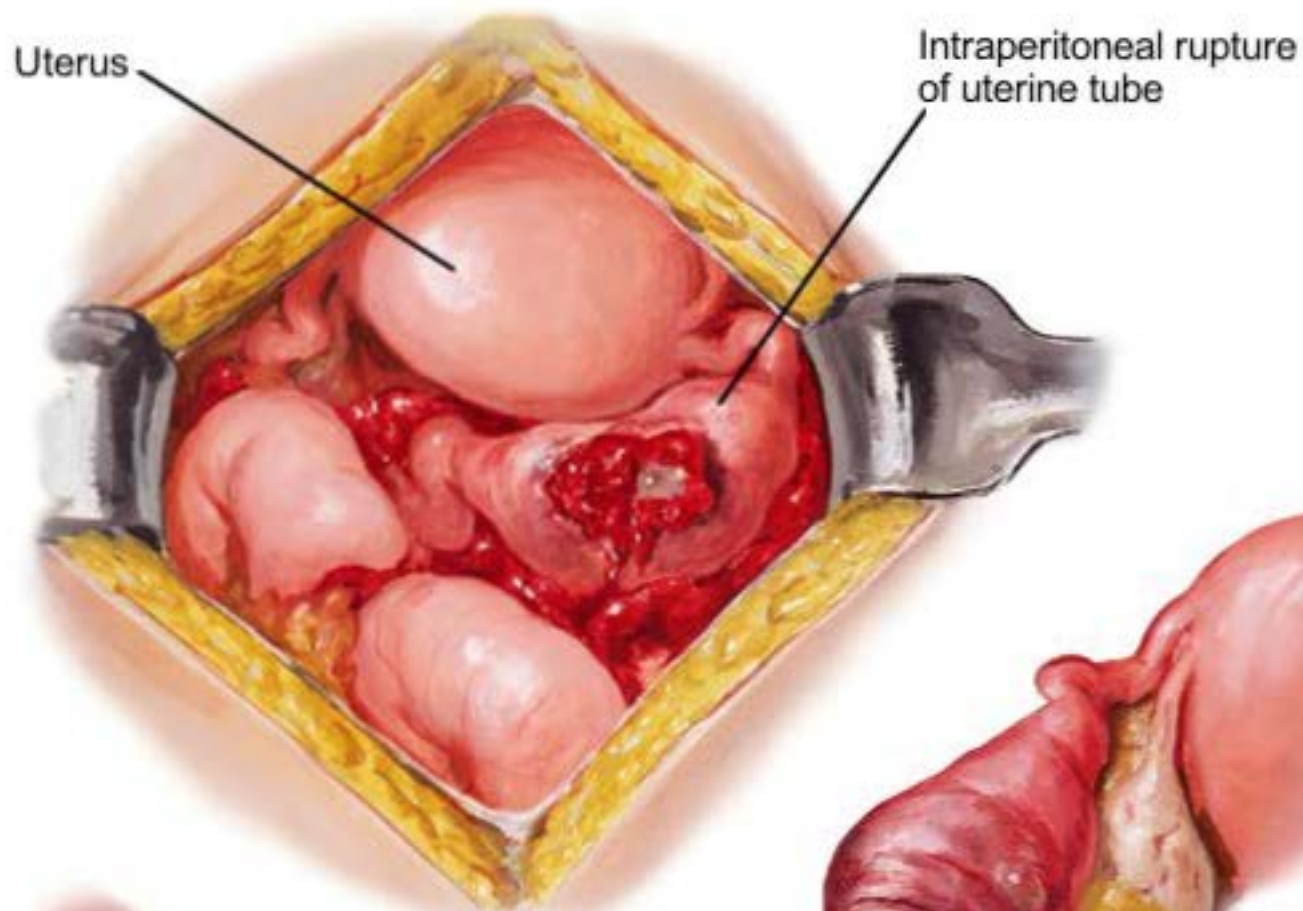
# Ectopic Pregnancy

## Sites of ectopic implantation

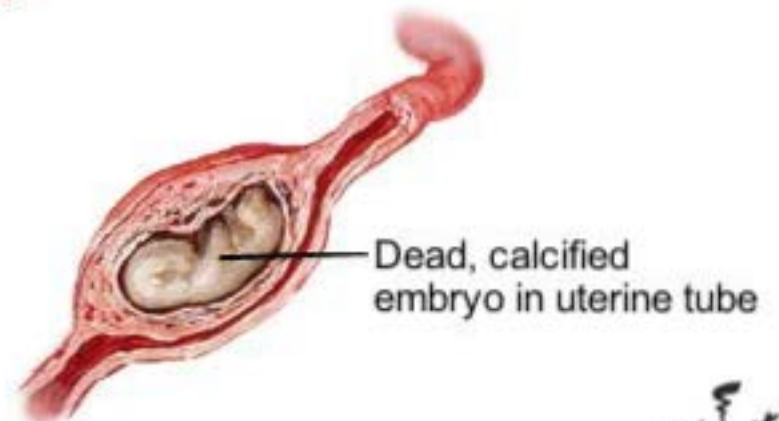
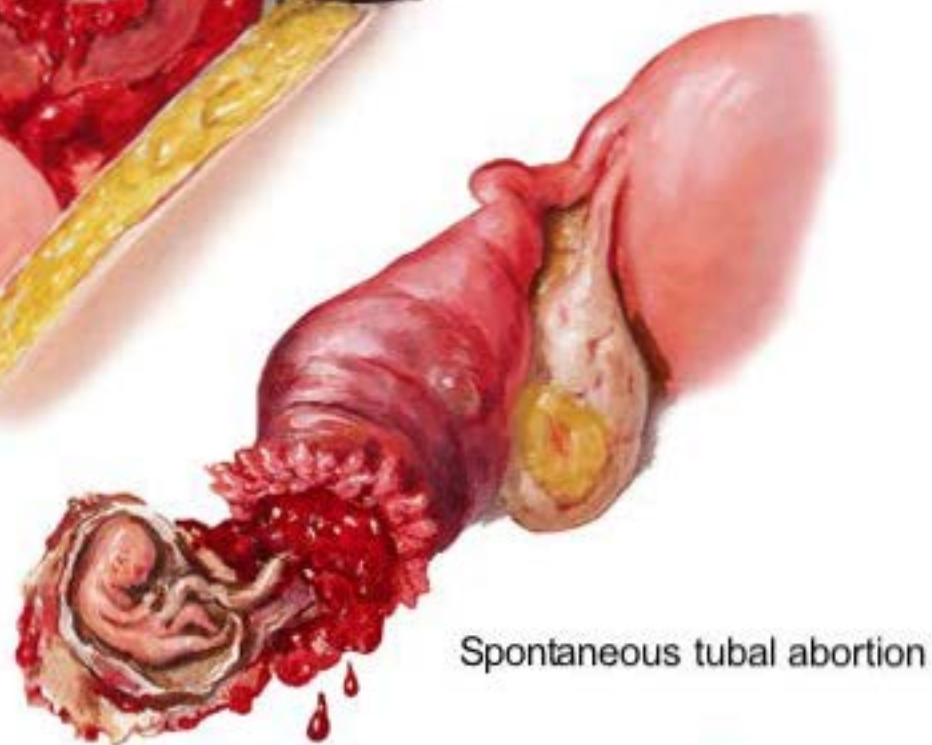




# Tubal Prenancy



Rupture into broad ligament



Lithopedion formation



# Interstitial, Abdominal, and Ovarian Pregnancy

**Interstitial pregnancy**

Uterus

Uterine tube

Placenta on the body wall,  
liver, stomach and intestines

**Abdominal pregnancy**

**Ovarian pregnancy**

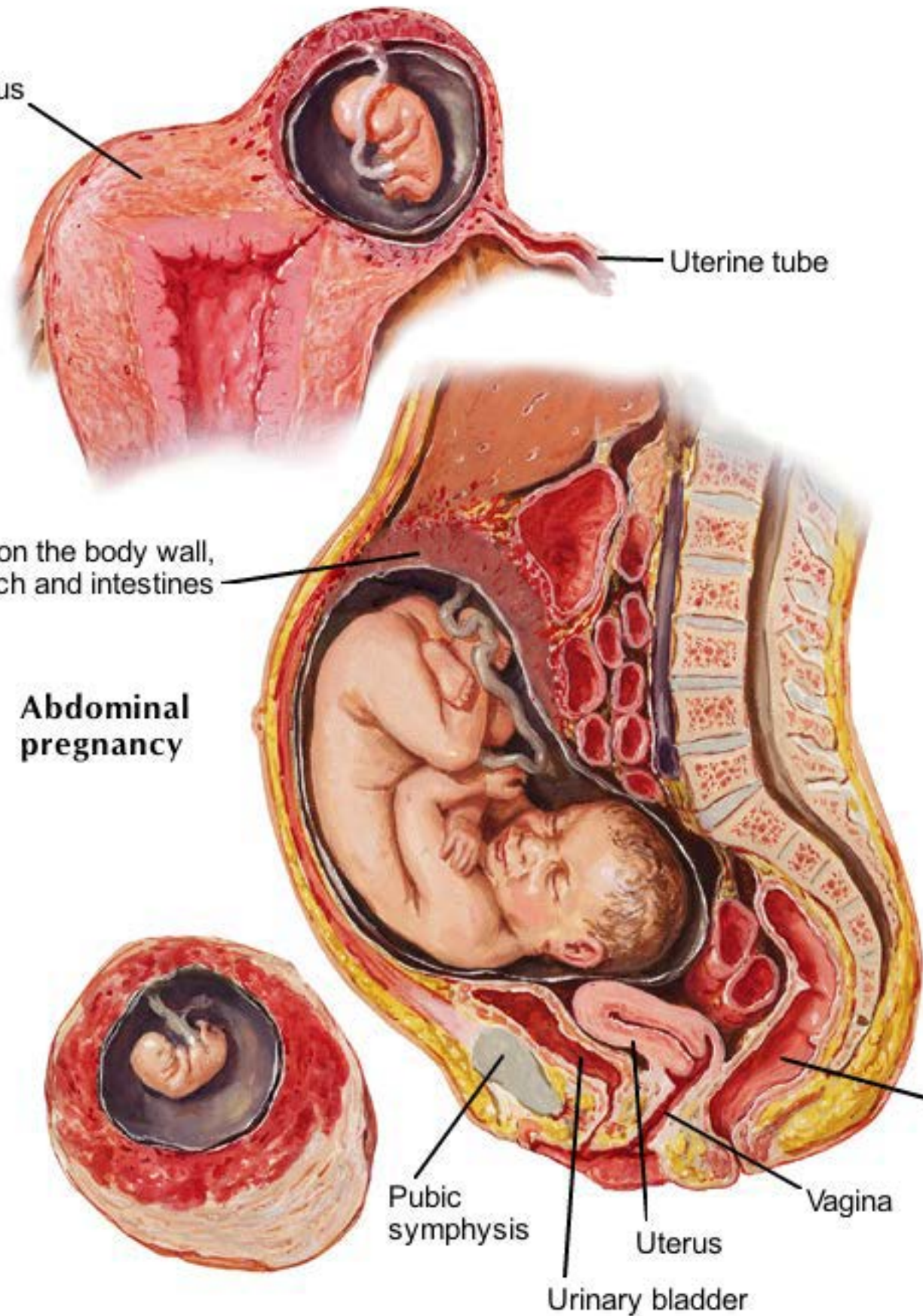
Pubic  
symphysis

Uterus

Urinary bladder

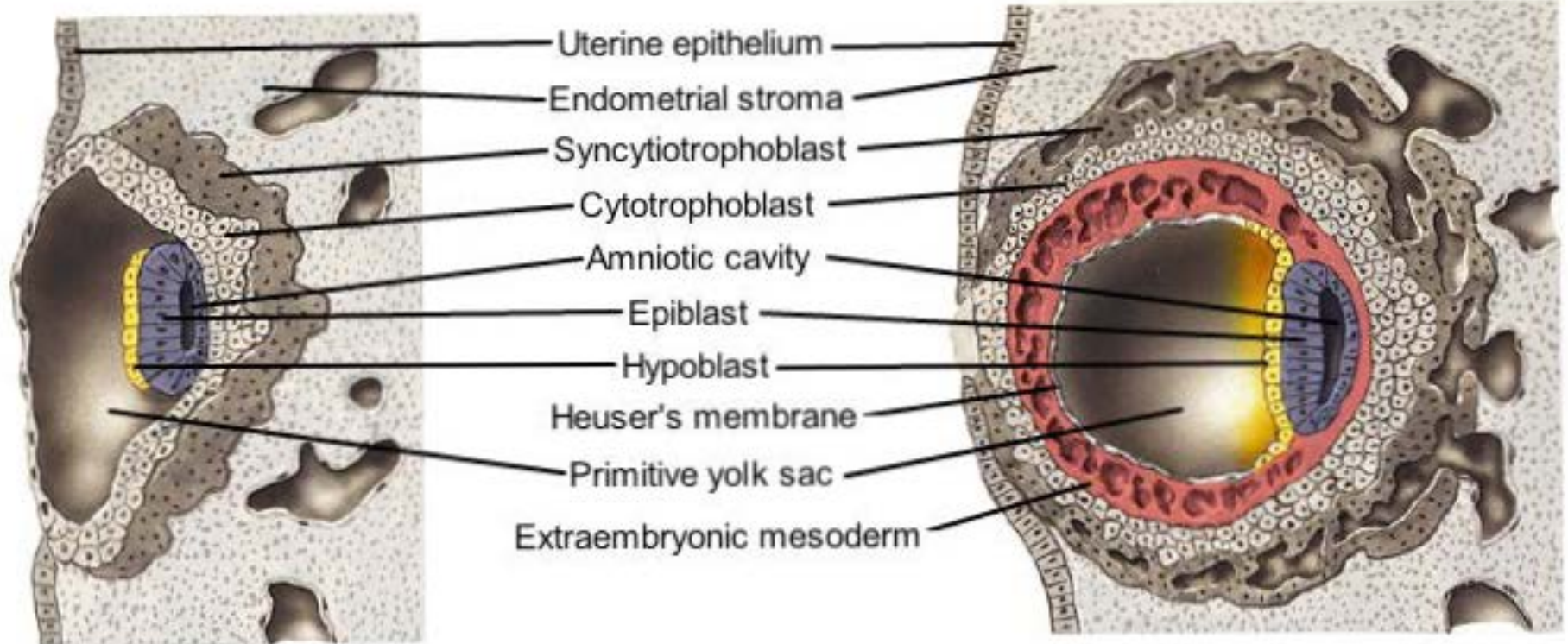
Vagina

Rectum



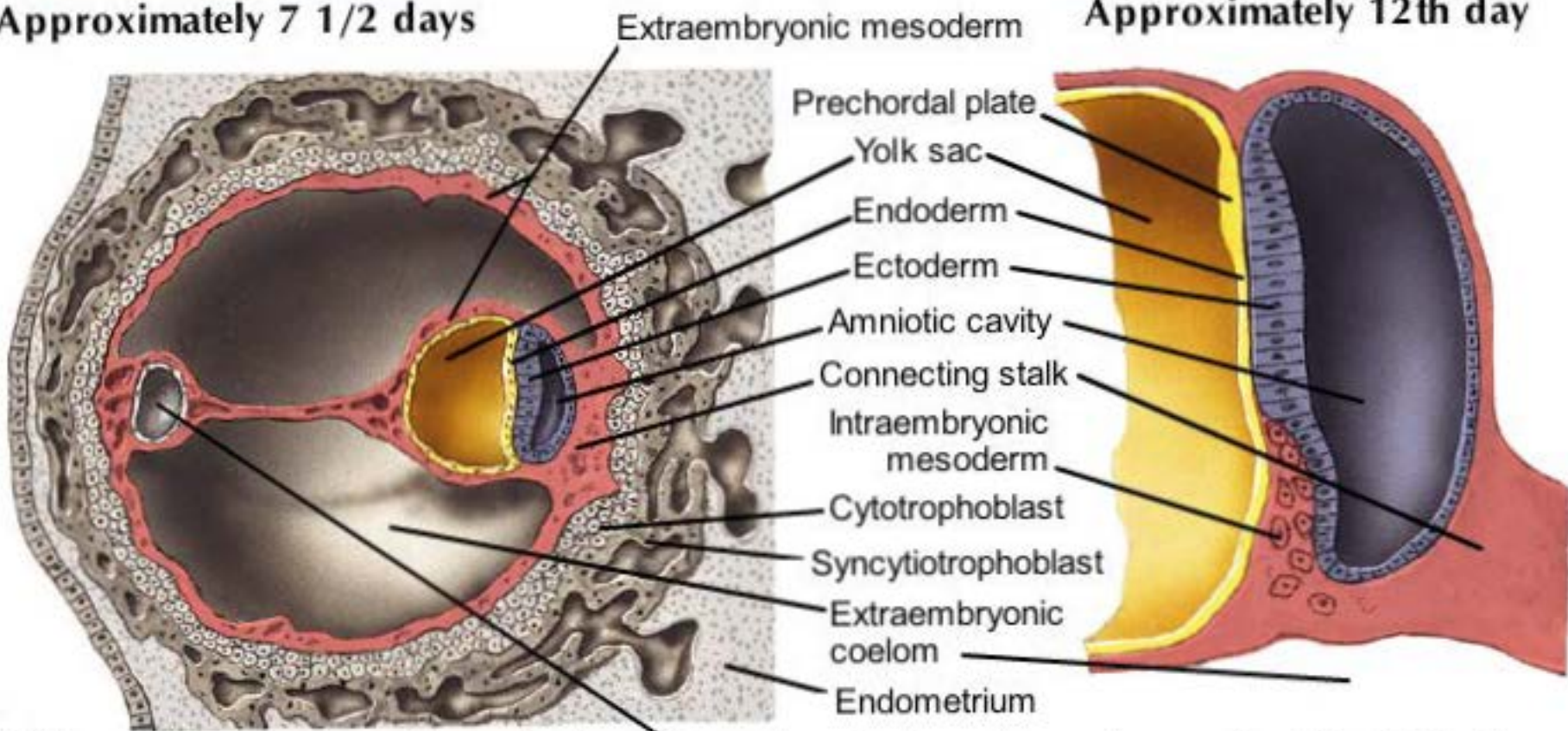


# The Second Week



Approximately 7 1/2 days

Approximately 12th day



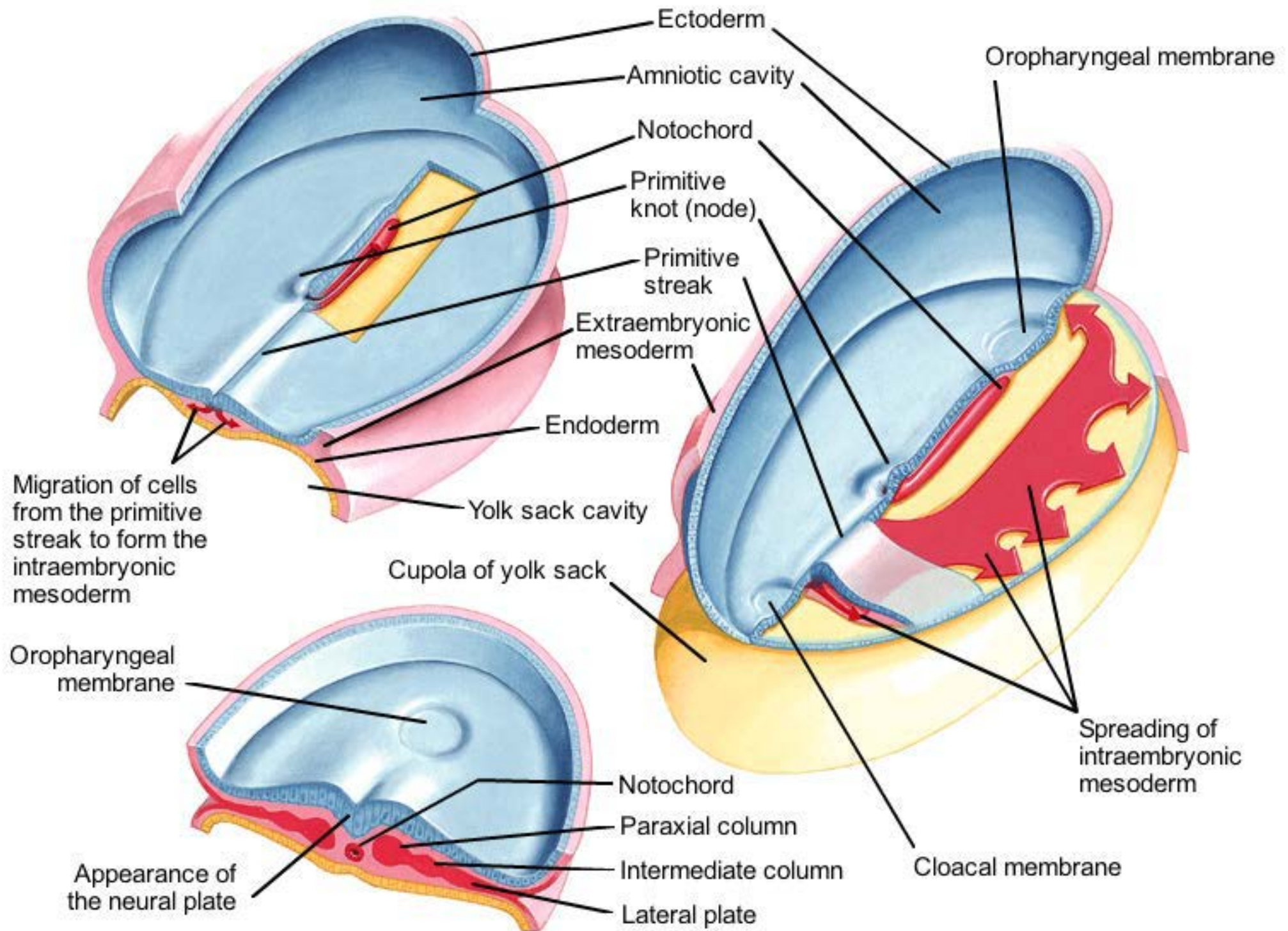
Approximately 15th day

Approximately 17th day



# The Third Week

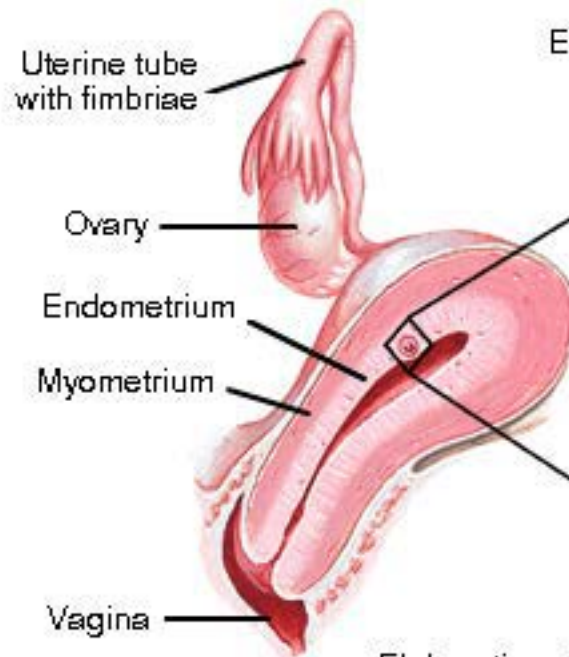
## Formation of Intraembryonic Mesoderm from the Primitive Streak and Node (Knot)



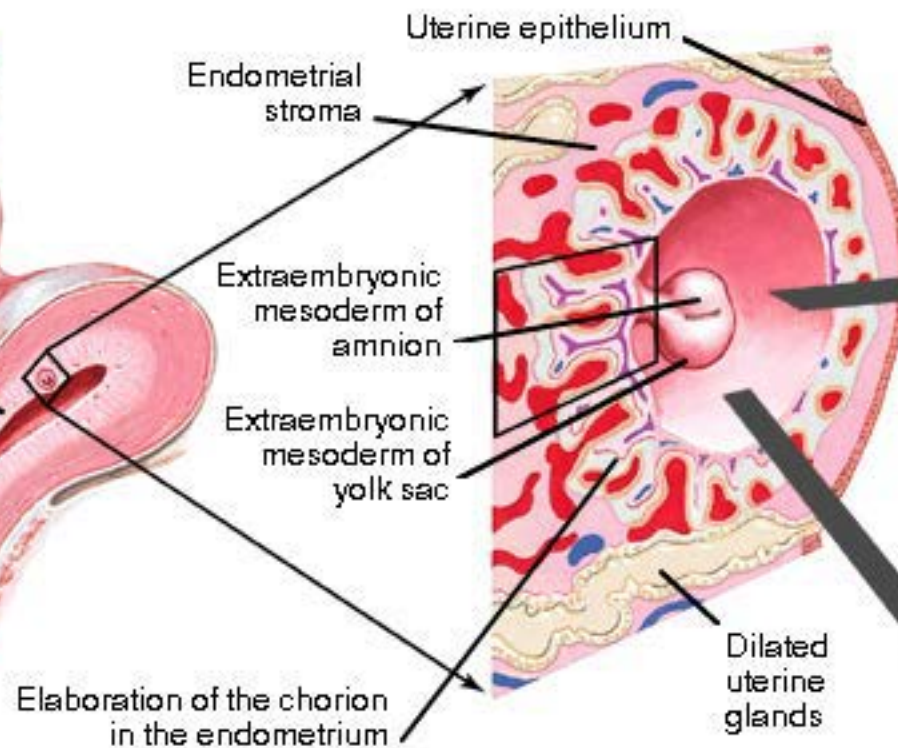


# Events Related to Gastrulation

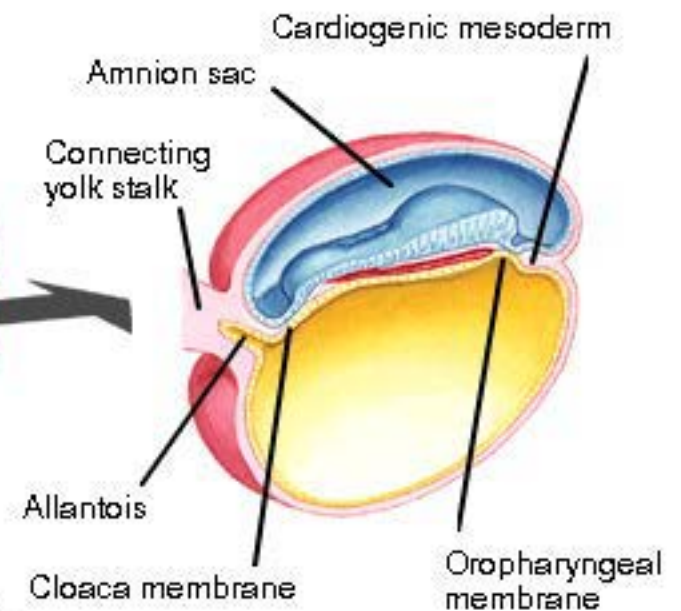
**Implantation site on the posterior wall of the uterus**



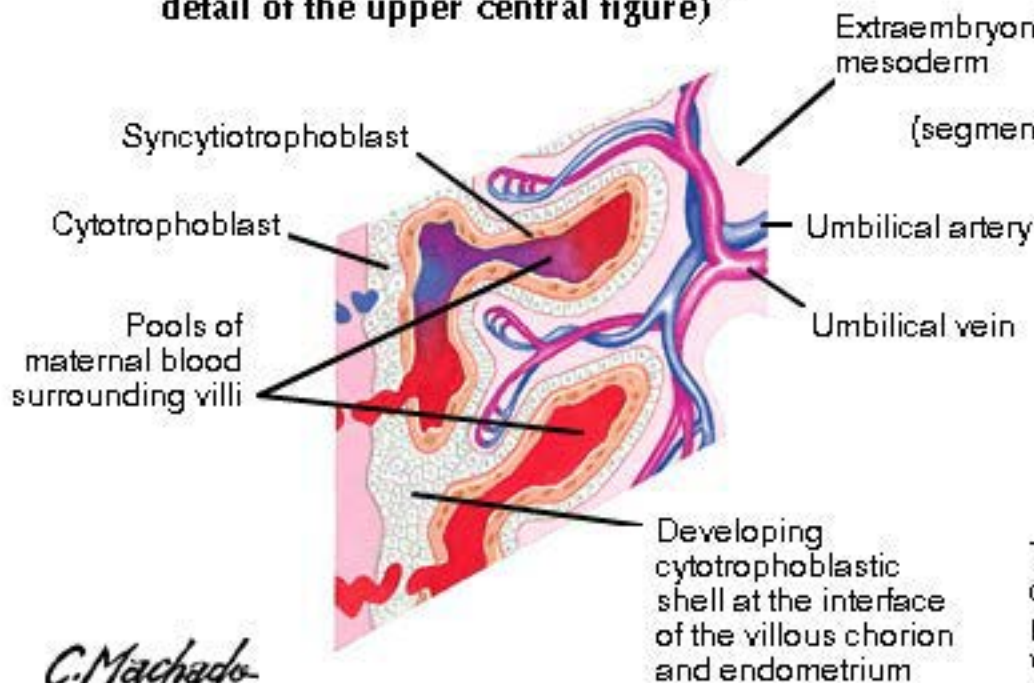
**Detail of the implantation site within the endometrium**



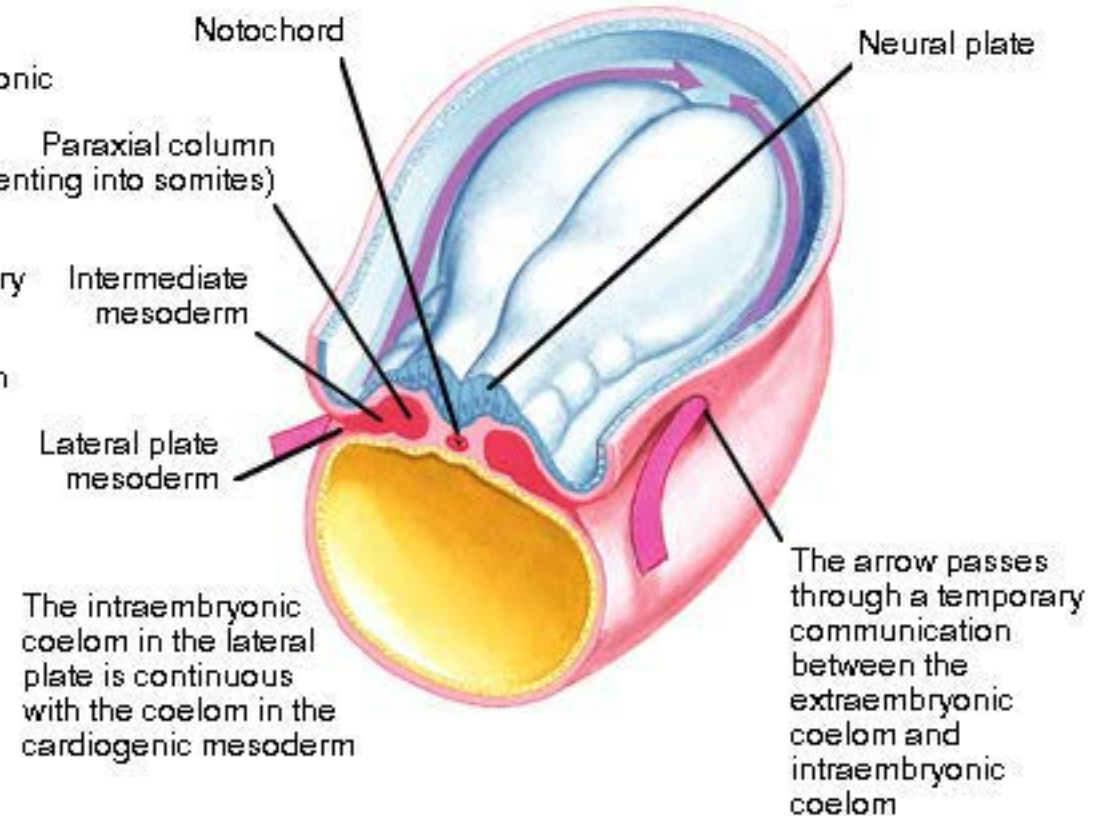
**Midsagittal section of embryo, amnion, and yolk sac**



**Early placenta development (enlarged detail of the upper central figure)**



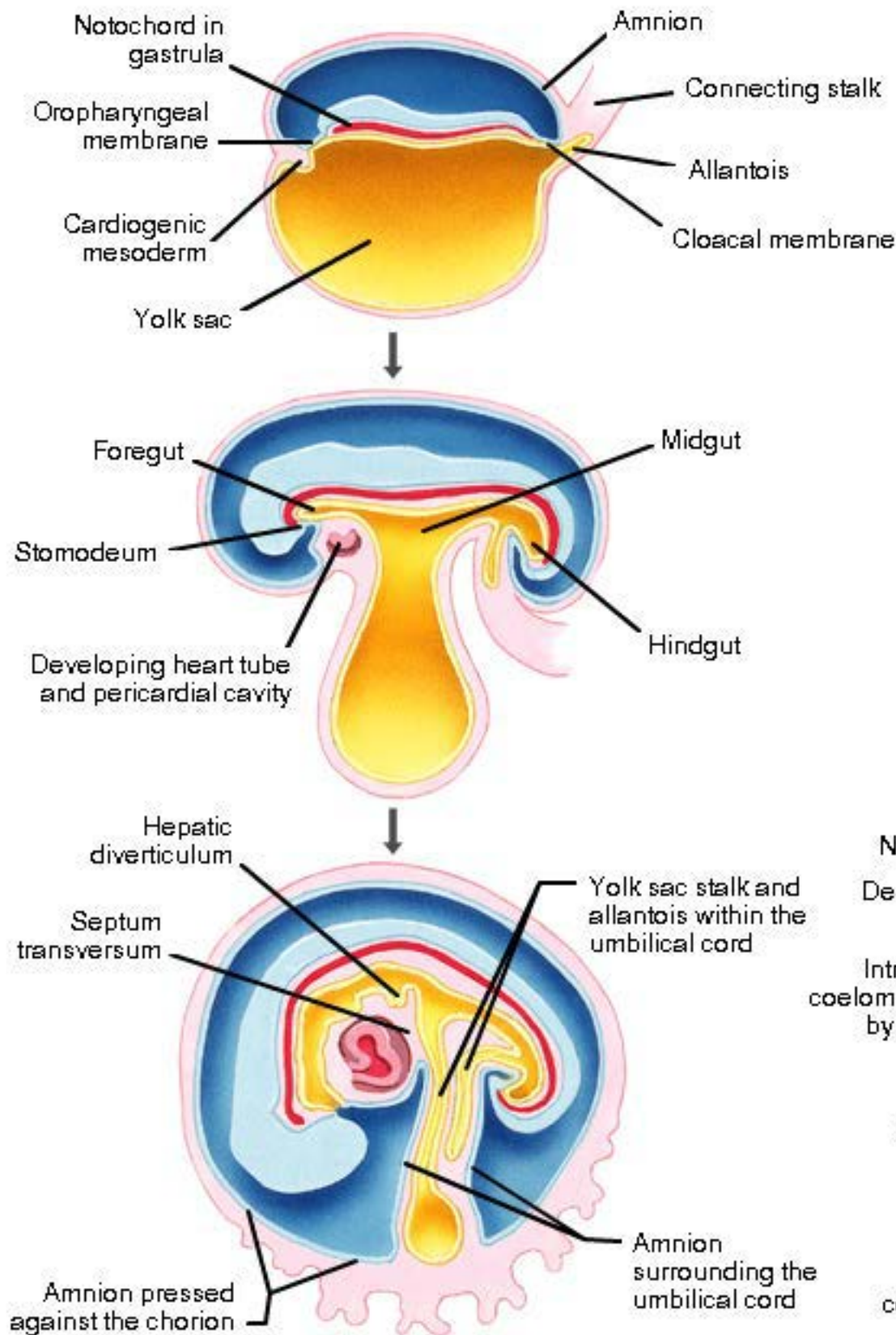
**Cross section of embryo**



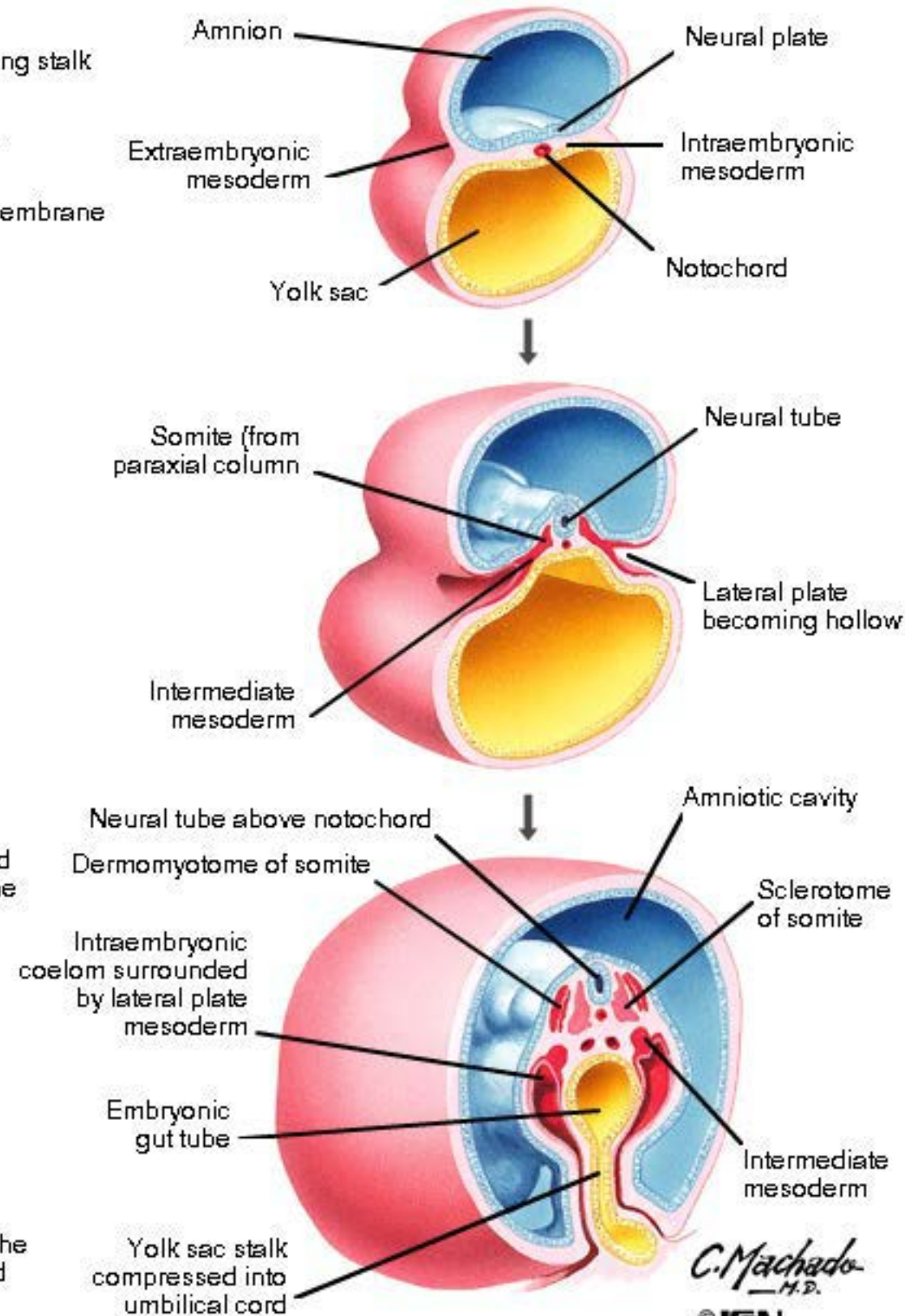


# Folding of the Embryo in Week 4

**Midsagittal section of folding gastrula**



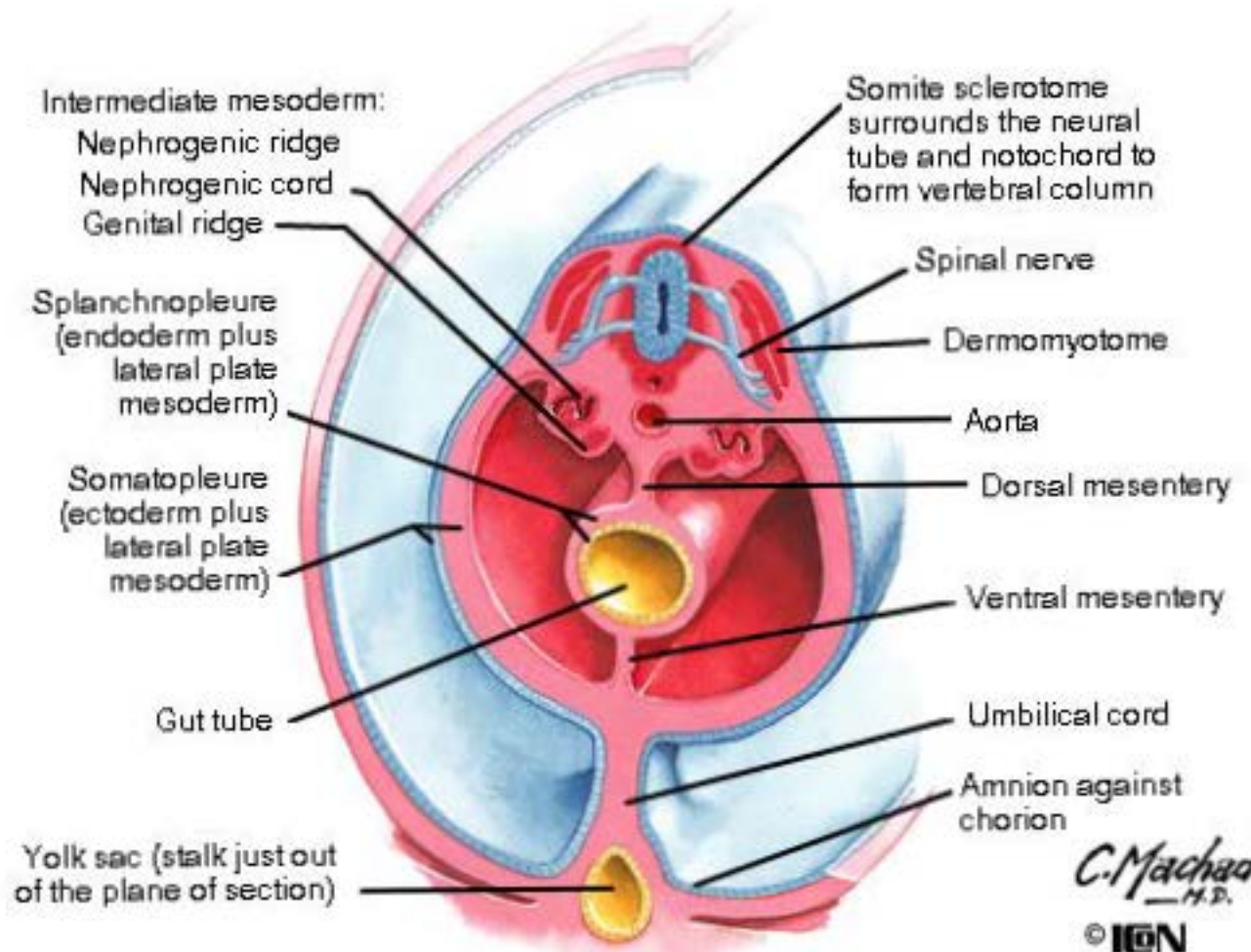
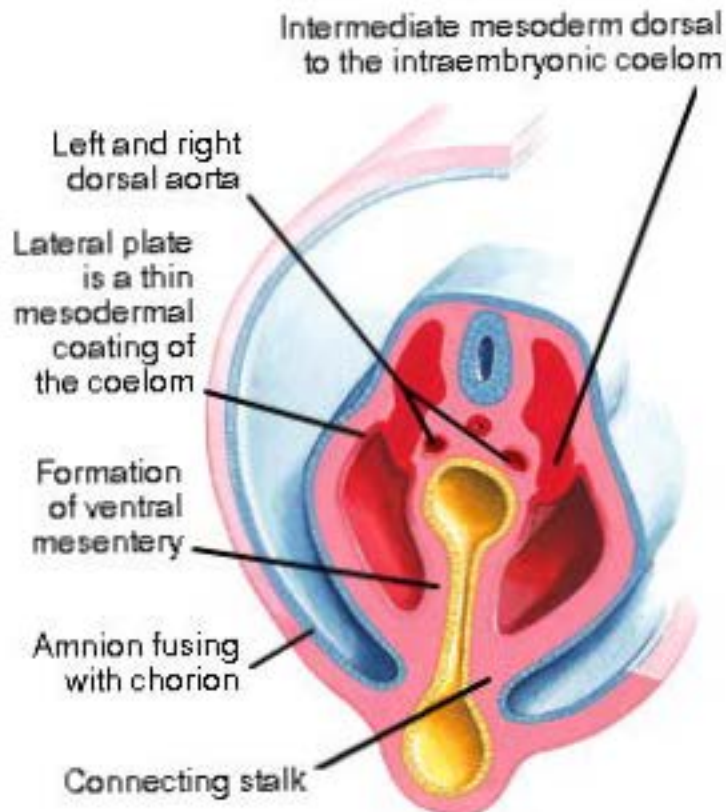
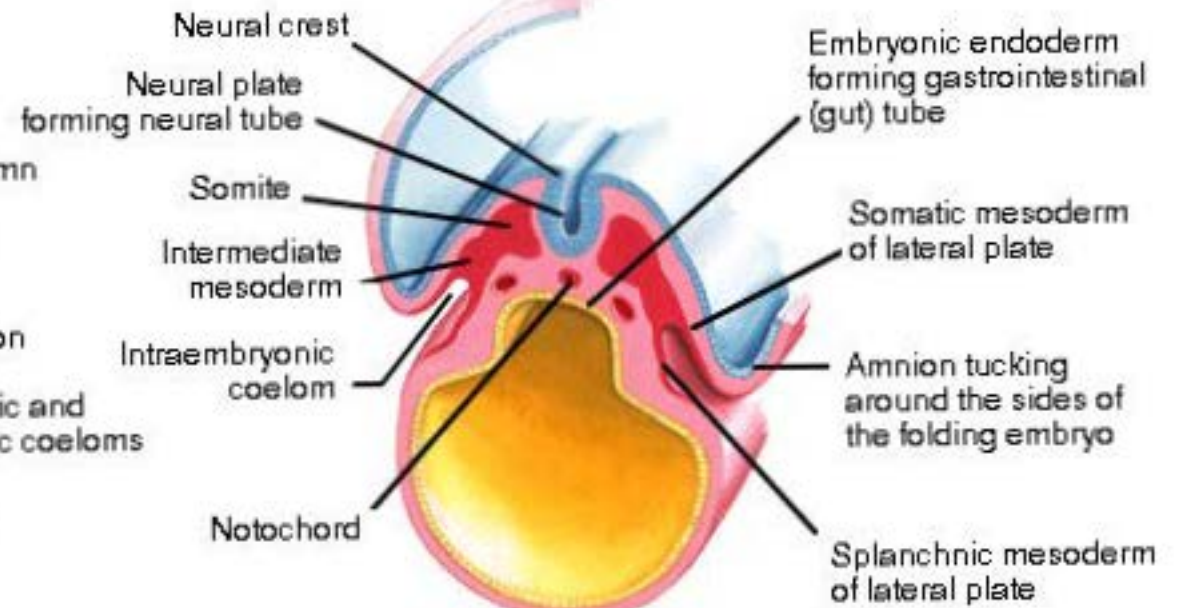
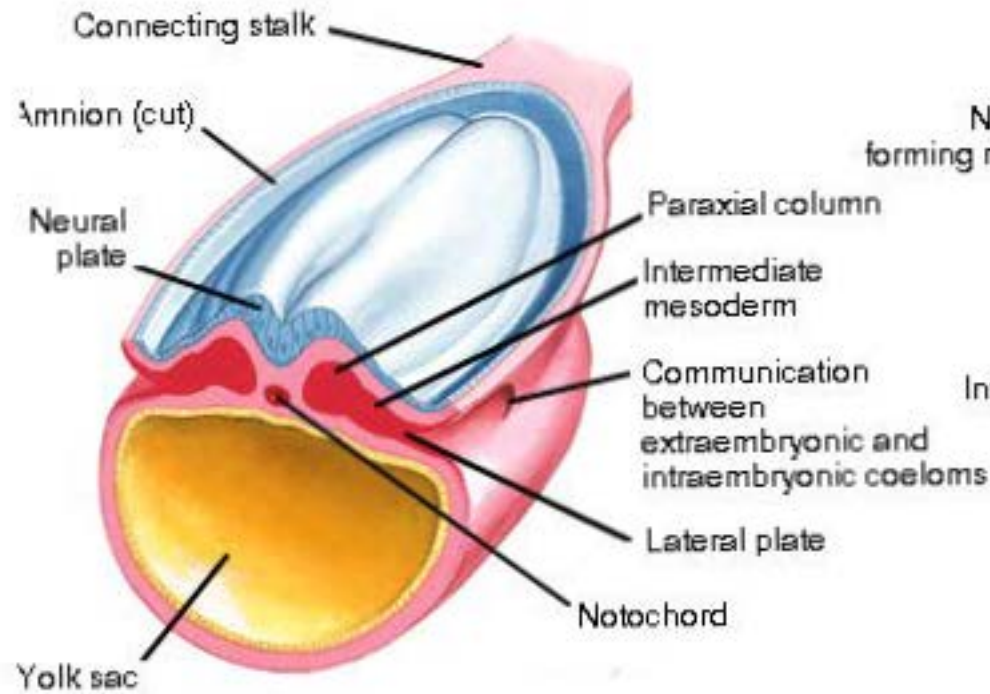
**Cross section of folding gastrula**





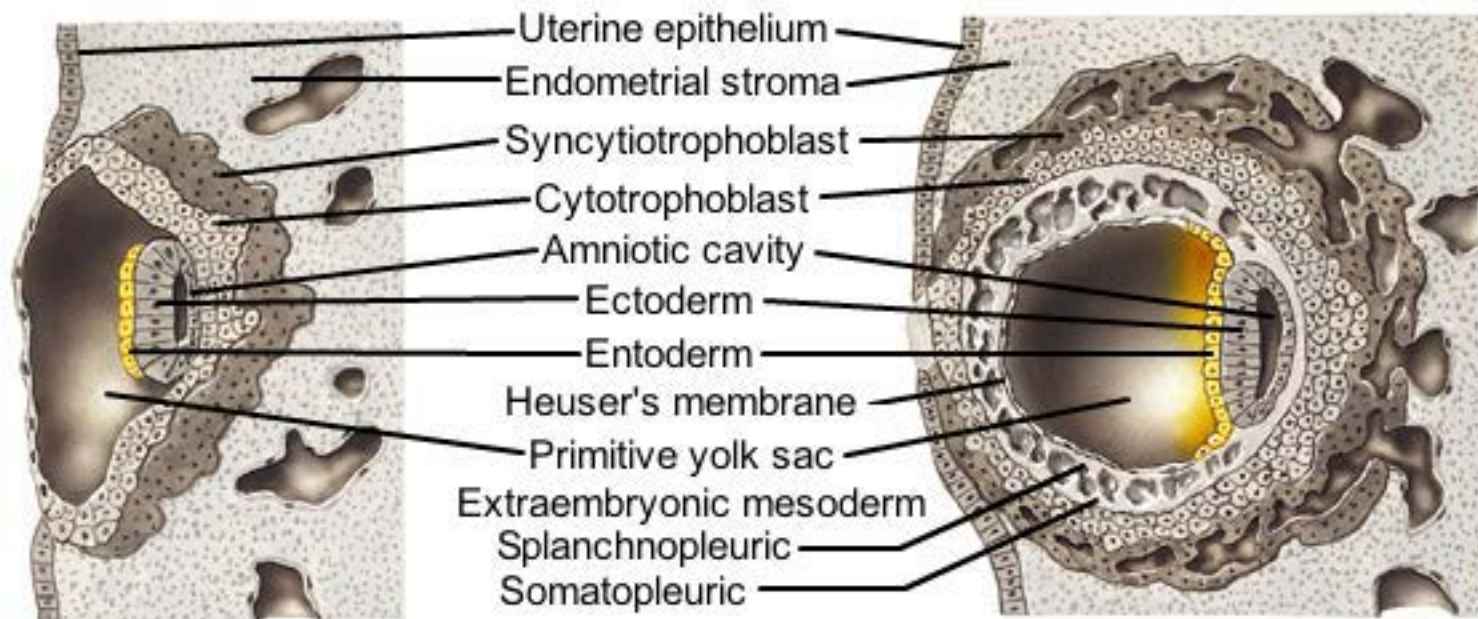
# The Vertebrate Body Plan

## Vertebrate Body Plan after 4 Weeks





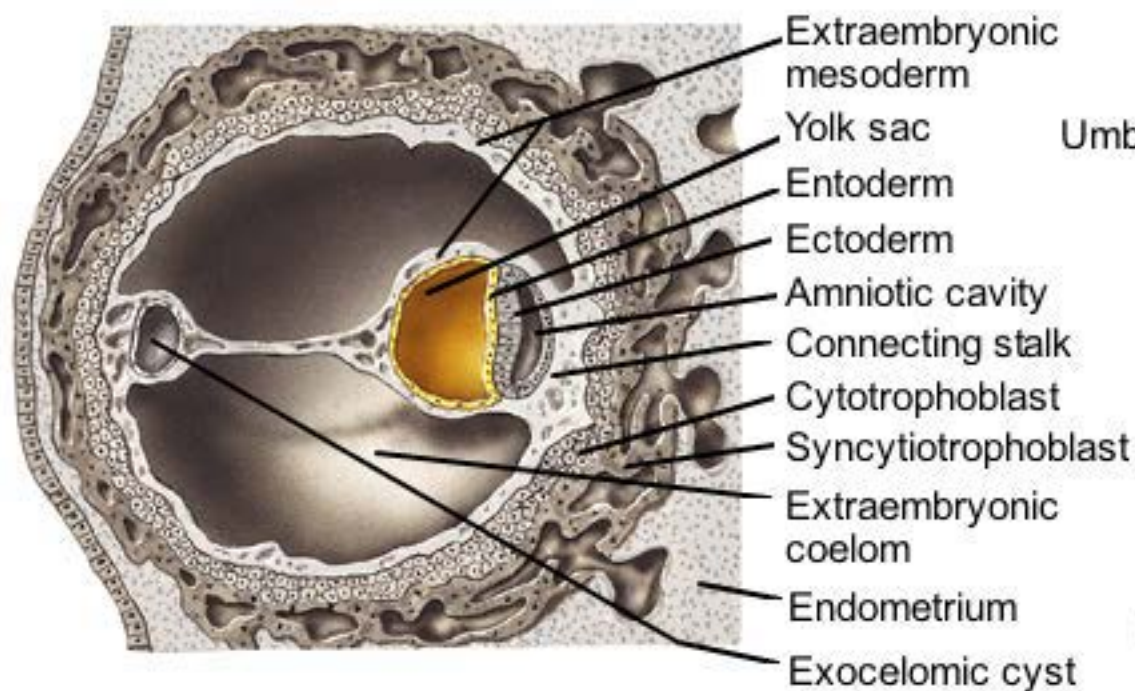
# Formation of the Placenta



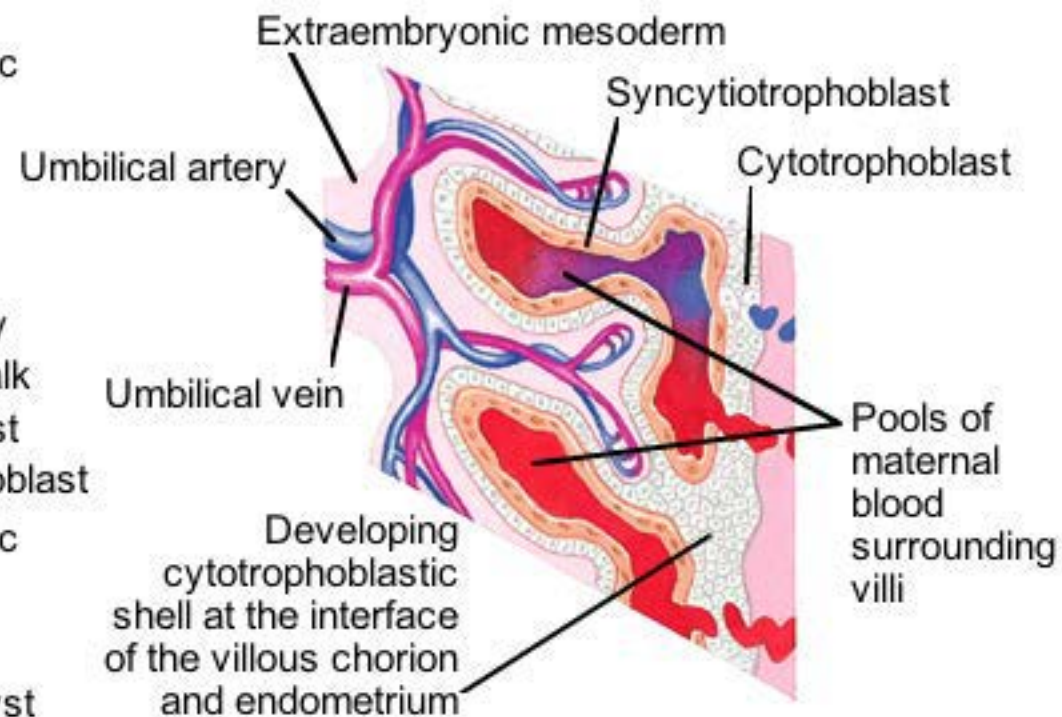
*F. Netter M.D.*  
*C. Machado M.D.*  
 © IGCN

Approximately 7 1/2 days

Approximately 12th day



Approximately 15th day

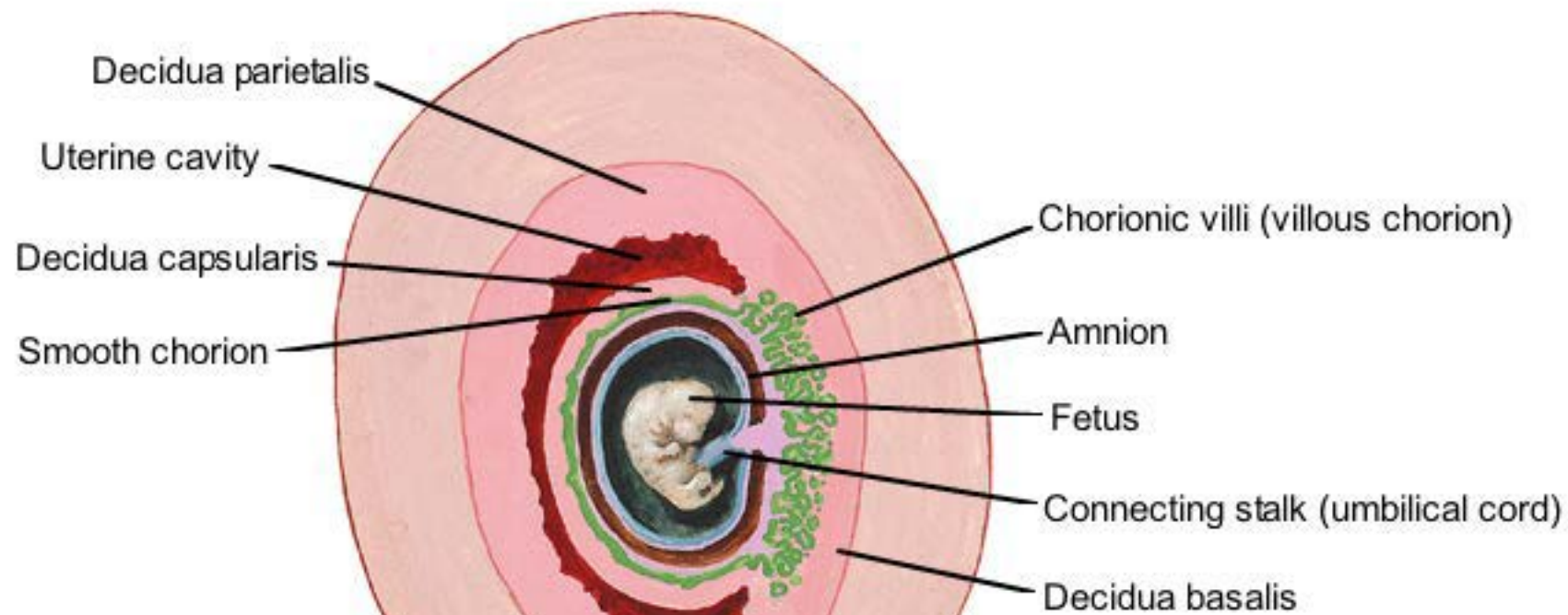


Approximately 25th day and the establishment of placental circulation

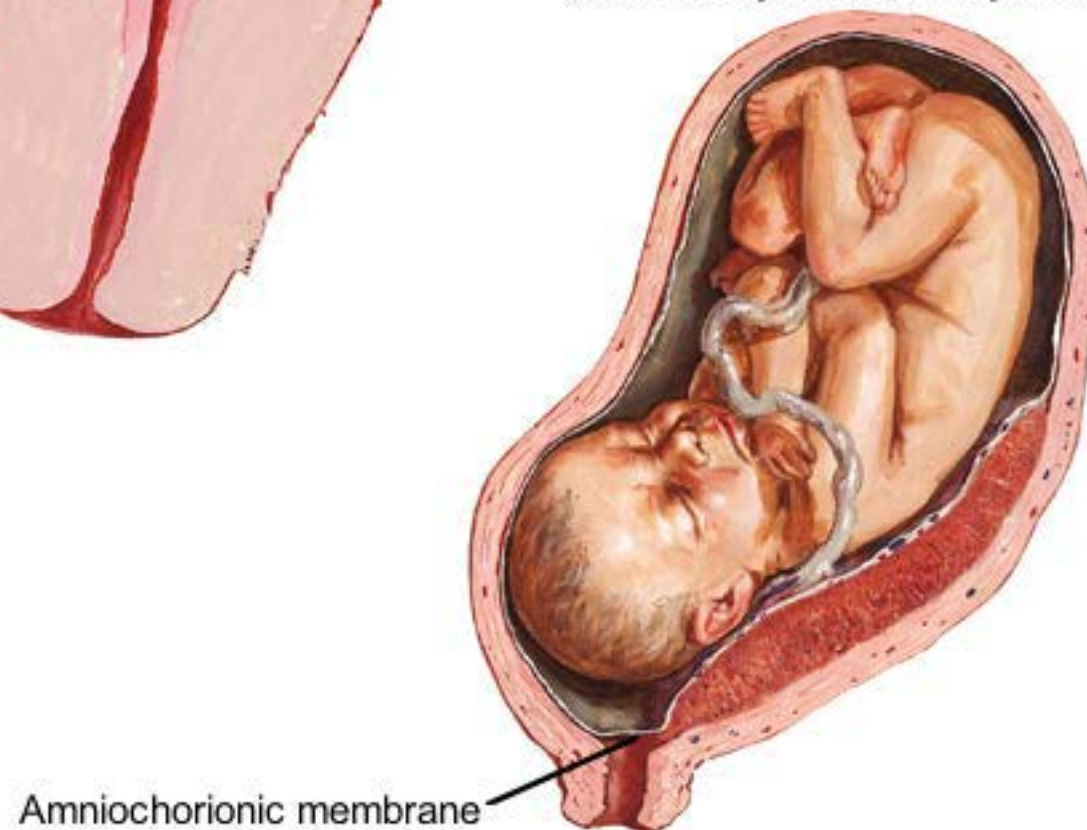


# The Endometrium and Fetal Membranes

Early fetal development and membrane formation in relation to the uterus as a whole (schematic)

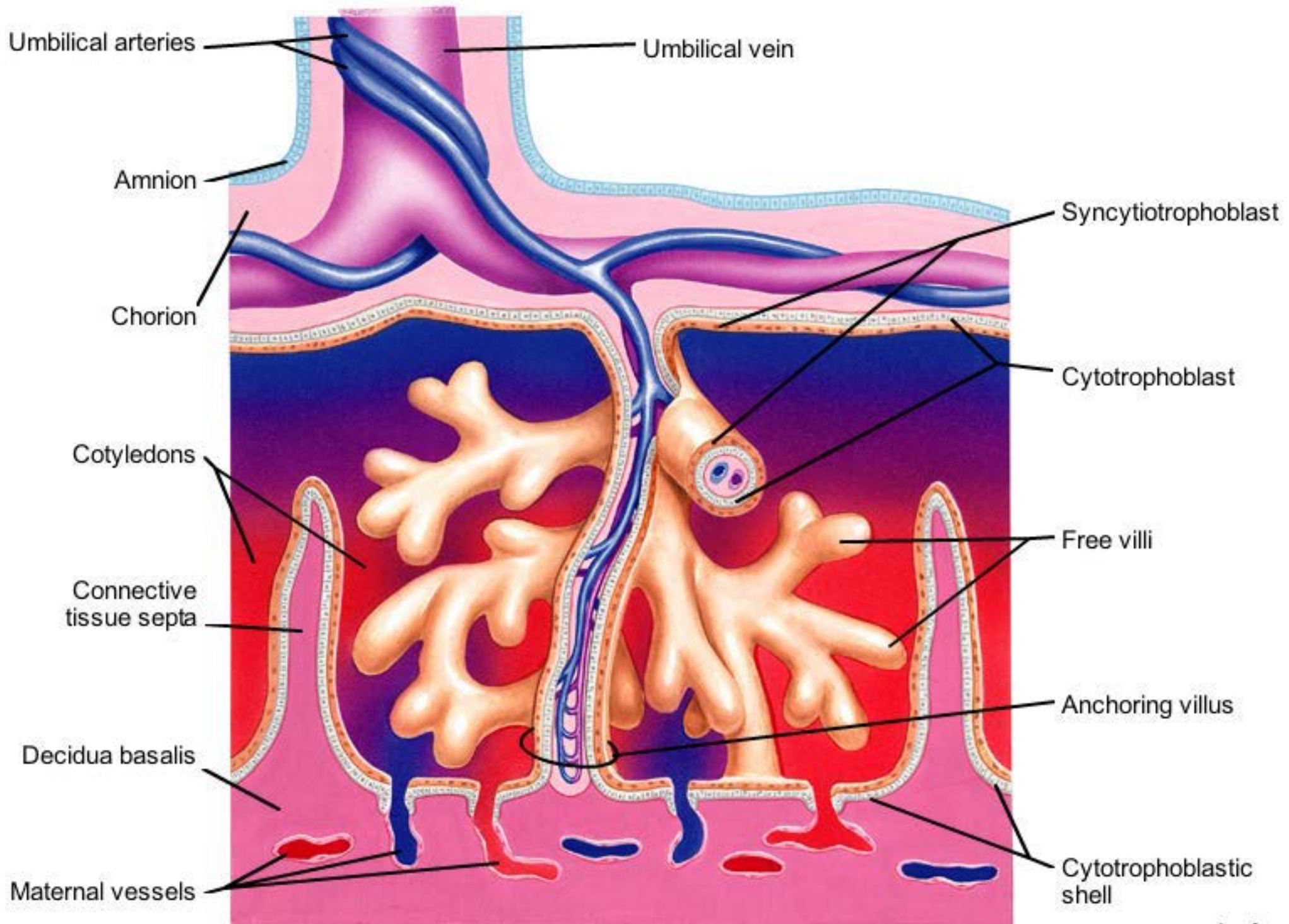


**Full-term fetus within the uterus  
(with low position of placenta)**



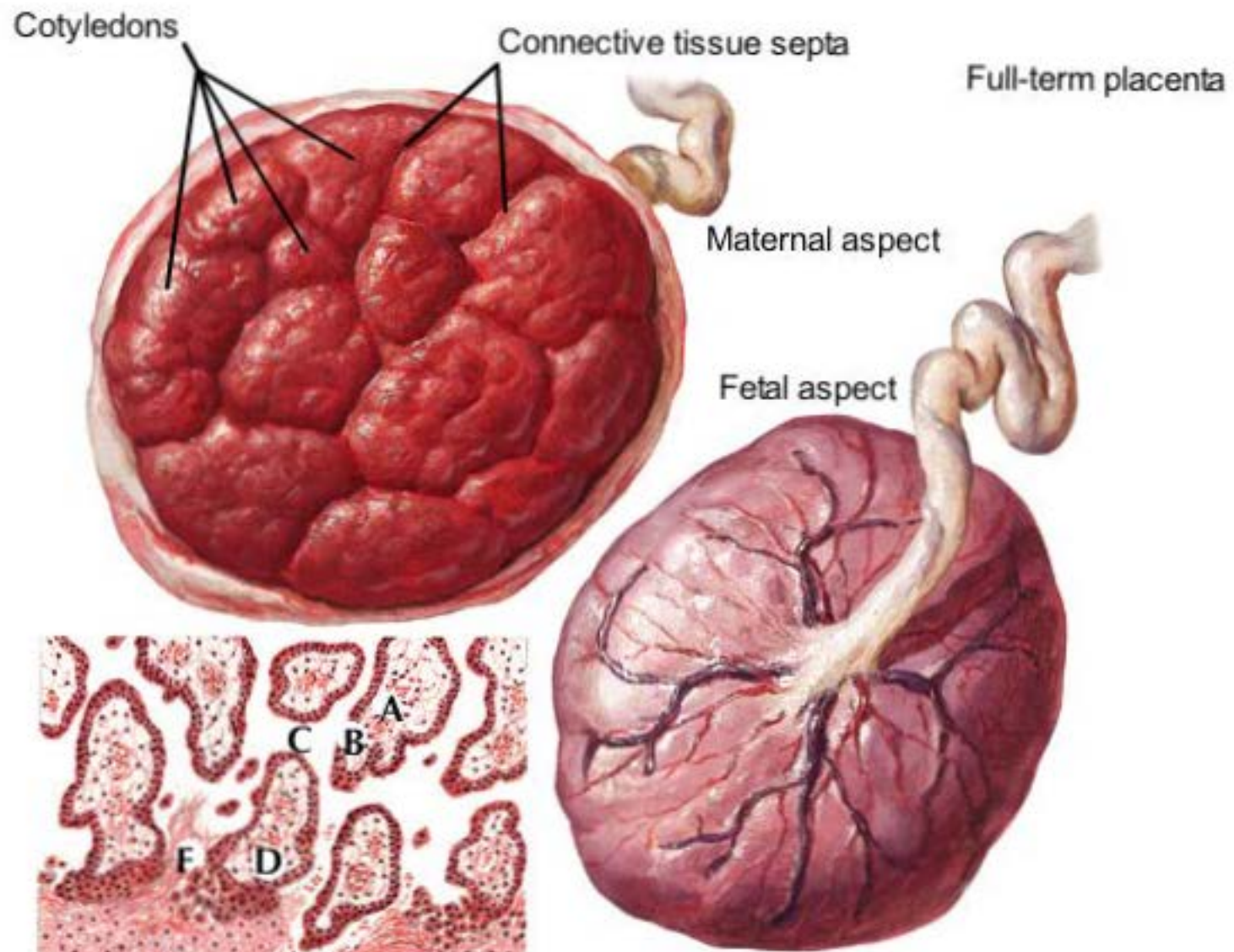
# Placental Structure

## Development of the placenta: chorionic villi





# Placental Structure



Section through deep portion of placenta-early gestation

(A) Villus, (B) trophoblast, (C) intervillous space, (D) anchoring villus, (E) villus invading blood vessel, (F) fibrinoid degeneration, (G) decidua basalis, (H) gland

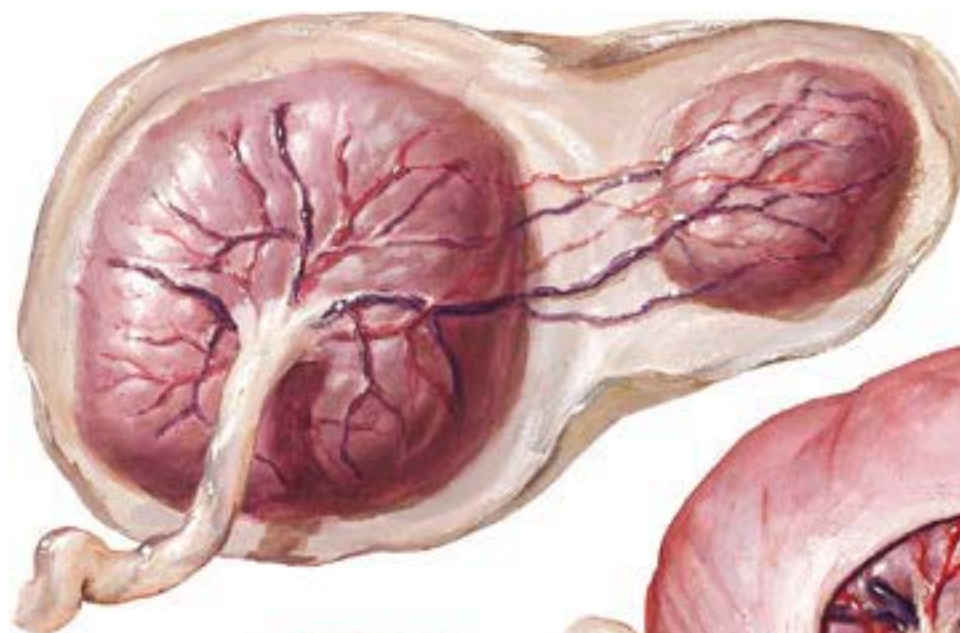
Appearance of placental villi at term

(A) Syncytial cell mass becoming trophoblastic embolus, (B) fetal blood vessel endothelium against a thinned syncytiotrophoblast, where they share a basal lamina. The cytotrophoblast has disappeared

*F. Netter M.D.*  
© IBN



# Placental Variations



Succenturiate  
placenta



Circumvallate placenta



Battledore placenta



Velamentous insertion of cord



# Placenta Previa

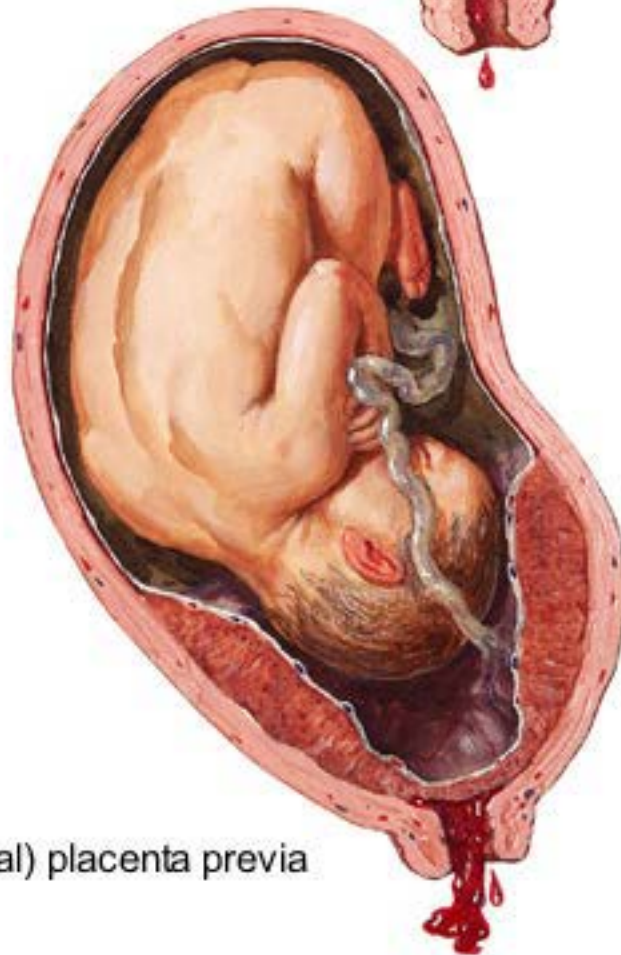
Marginal placenta previa



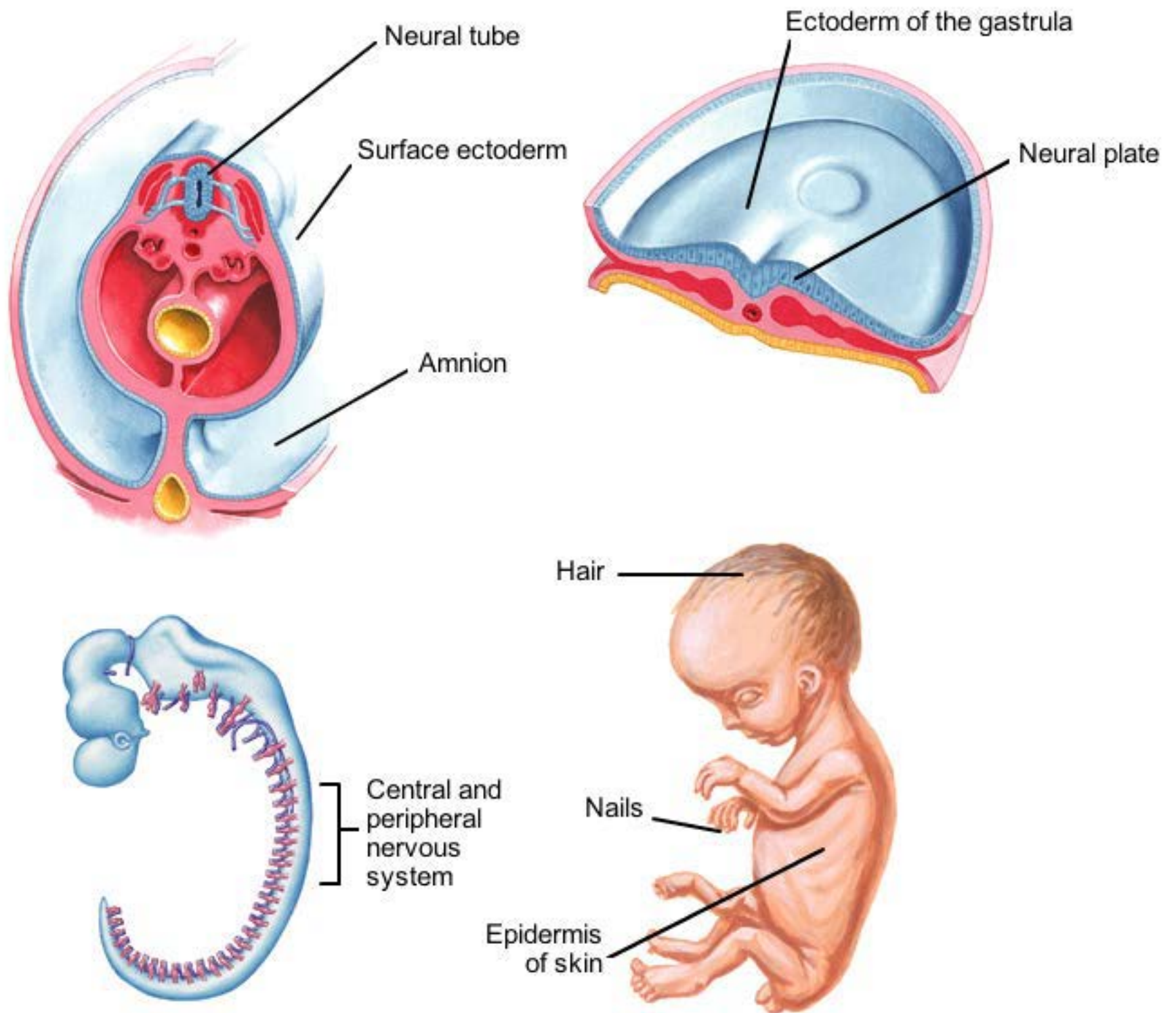
Partial placenta previa



Total (central) placenta previa

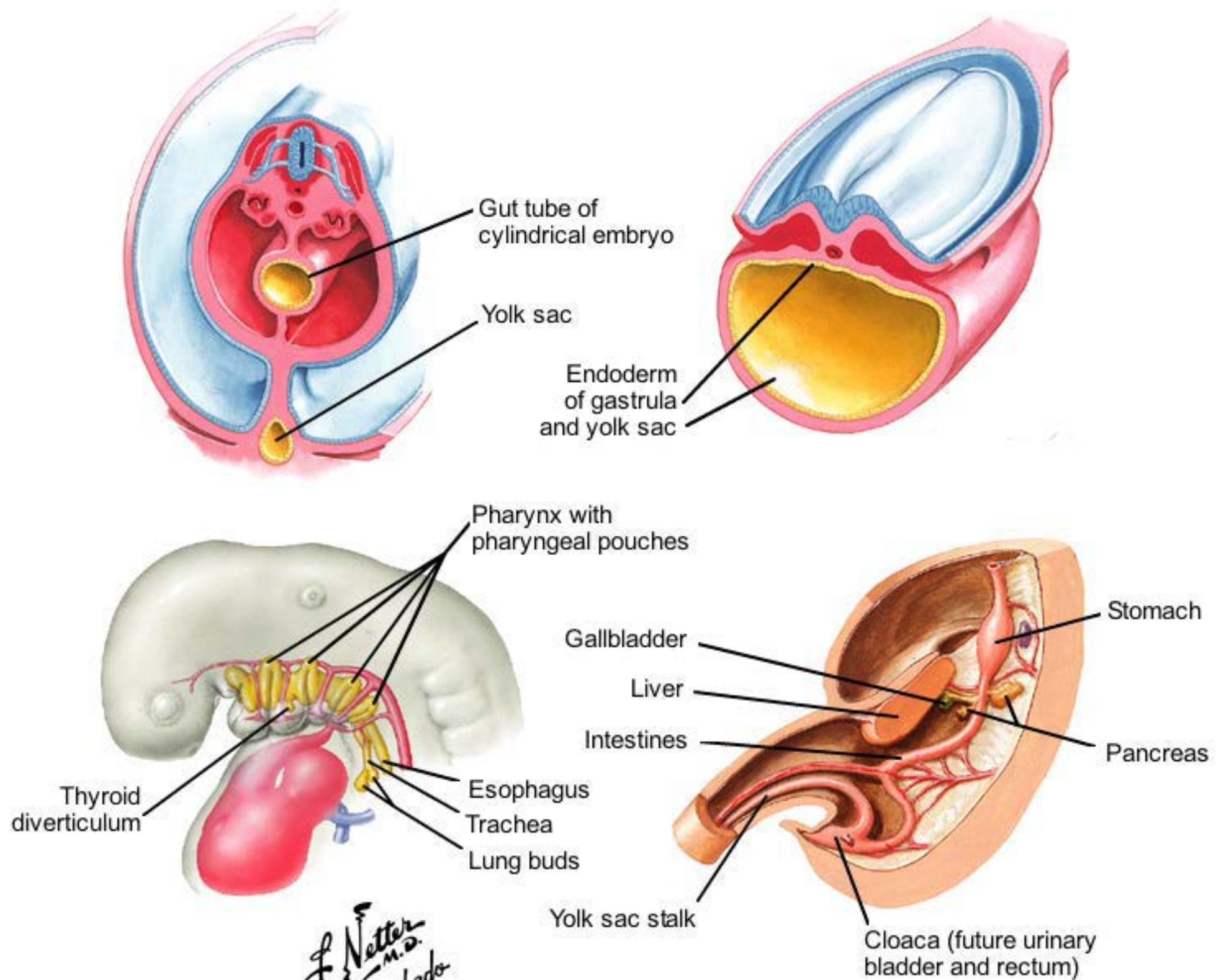


# Summary of Ectodermal Derivatives

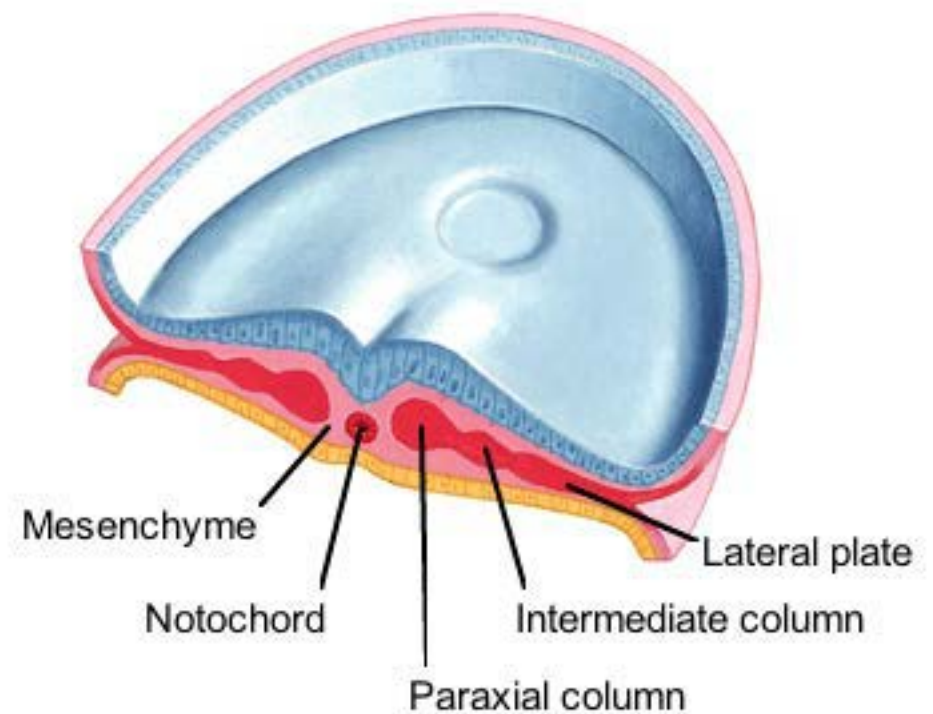
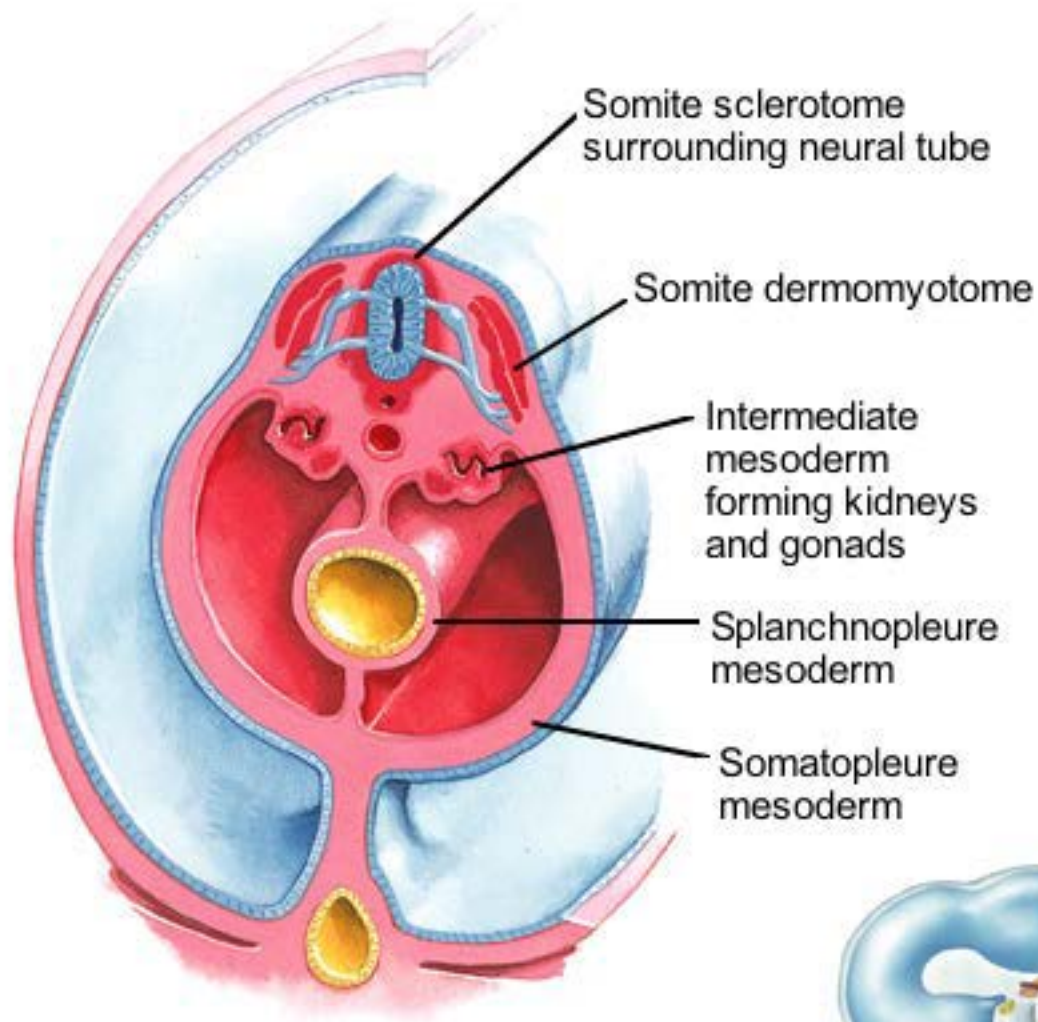




# Summary of Endodermal Derivatives



# Summary of Mesodermal Derivatives



Axial and appendicular skeleton, 5 weeks



Developing skeletal muscles, 8 weeks



## Chart 2.1 Ectodermal Derivatives

Primordia	Derivatives or Fate
Surface ectoderm  (Stomodeum and nasal placodes) (Otic placodes) (Lens placodes)	Epidermis of the skin Sweat, sebaceous, and mammary glands Nails and hair Tooth enamel Lacrimal glands Conjunctiva External auditory meatus Oral and nasal epithelium Anterior pituitary Inner ear Lens of eye
Neural tube	Central nervous system Somatomotor neurons Branchiomotor neurons Presynaptic autonomic neurons Retina/optic nerves Posterior pituitary
Neural crest	Peripheral sensory neurons Postsynaptic autonomic neurons All ganglia Adrenal medulla cells Melanocytes Bone, muscle, and connective tissue in the head and neck
Amnion	Protective bag (with chorion) around fetus

## Chart 2.2 Endodermal Derivatives

CHART 2.2 ENDODERMAL DERIVATIVES

Primordia	Epithelial Derivatives or Fate
Gut tube endoderm	GI tract (enterocytes) Mucosal glands of GI tract Parenchyma of GI organs (liver, pancreas) Airway lining (larynx, trachea, bronchial tree) Thyroid gland Tonsils
Cloaca (part of hindgut)	Rectum and anal canal Bladder, urethra, and related glands Vestibule Lower vagina
Pharyngeal pouches (part of foregut)	Auditory tube and middle ear epithelium Palatine tonsil crypts Thymus gland Parathyroid glands C cells of the thyroid gland
Yolk sac	Embryonic blood cell production (mesoderm) Pressed into umbilical cord, then disappears
Allantois (from yolk sac, then cloaca)	Embryonic blood cell production (mesoderm) Vestigial, fibrous urachus Umbilical cord part disappears

*GI*, Gastrointestinal.



## Chart 2.3 Mesodermal Derivatives

CHART 2.3 MESODERMAL DERIVATIVES

Primordia	Derivatives or Fate
Notochord	Nucleus pulposus of an intervertebral disc Induces neurulation
Paraxial columns (somites)	Skeletal muscle Bone Connective tissue (e.g., dorsal dermis, meninges)
Intermediate mesoderm	Gonads Kidneys and ureters Uterus and uterine tubes Upper vagina Ductus deferens, epididymis, and related tubules Seminal vesicles and ejaculatory ducts
Lateral plate mesoderm	Dermis (ventral) Superficial fascia and related tissues (ventral) Bones and connective tissues of limbs Pleura and peritoneum GI tract connective tissue stroma
Cardiogenic mesoderm	Heart Pericardium

*GI*, Gastrointestinal.

# THE NERVOUS SYSTEM TIMELINE

Prenatal Time Scale (Months)

End of 4th week



Flexures and swellings distinguish the forebrain (prosencephalon), midbrain (mesencephalon), and hindbrain (rhombencephalon).

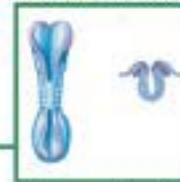
End of 5th week



Forebrain divides into the diencephalon and telencephalon (future cerebral cortex).

Blastocyst

3rd week



Neurulation.

5th week



Spinal nerves grow into the body wall; autonomic nerves grow into the viscera within the body cavities.

3 Months



Cerebral cortex (telencephalon) overgrows the midbrain.

6 months



Primary gyri begin to appear.

9

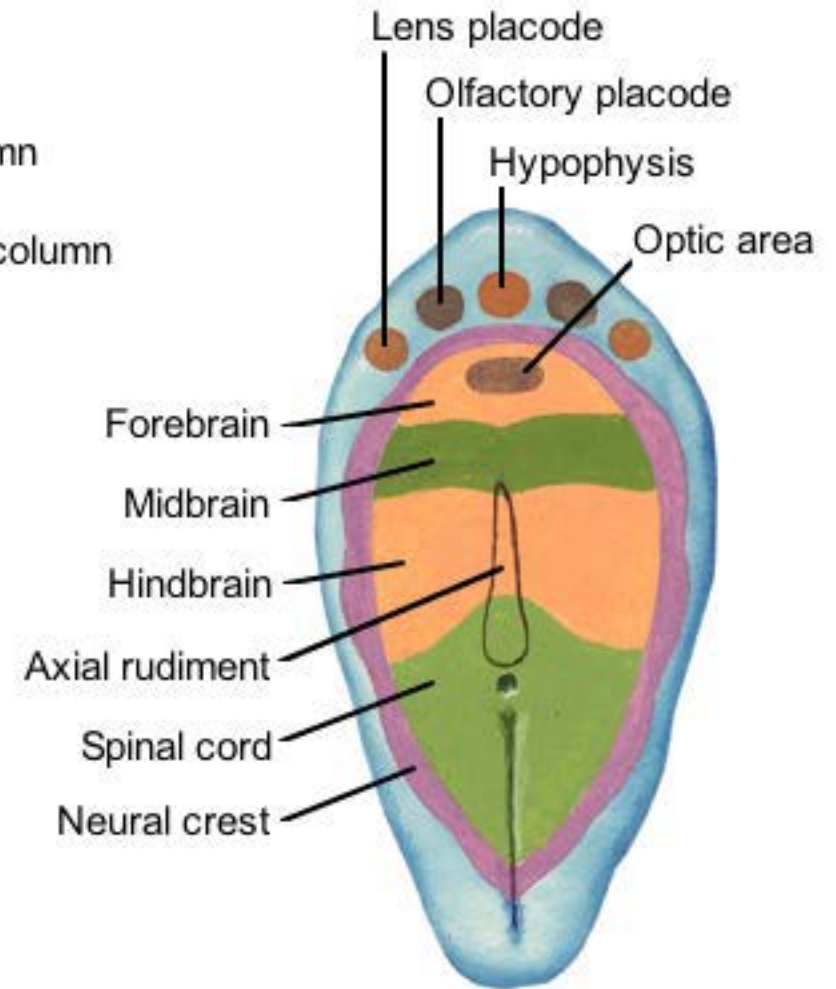
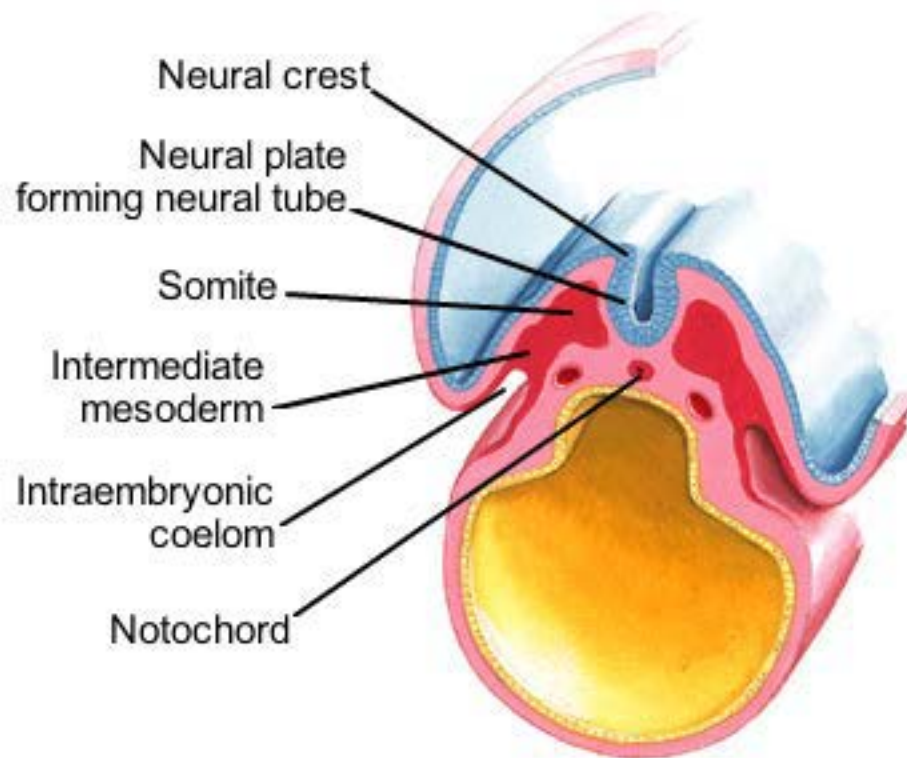
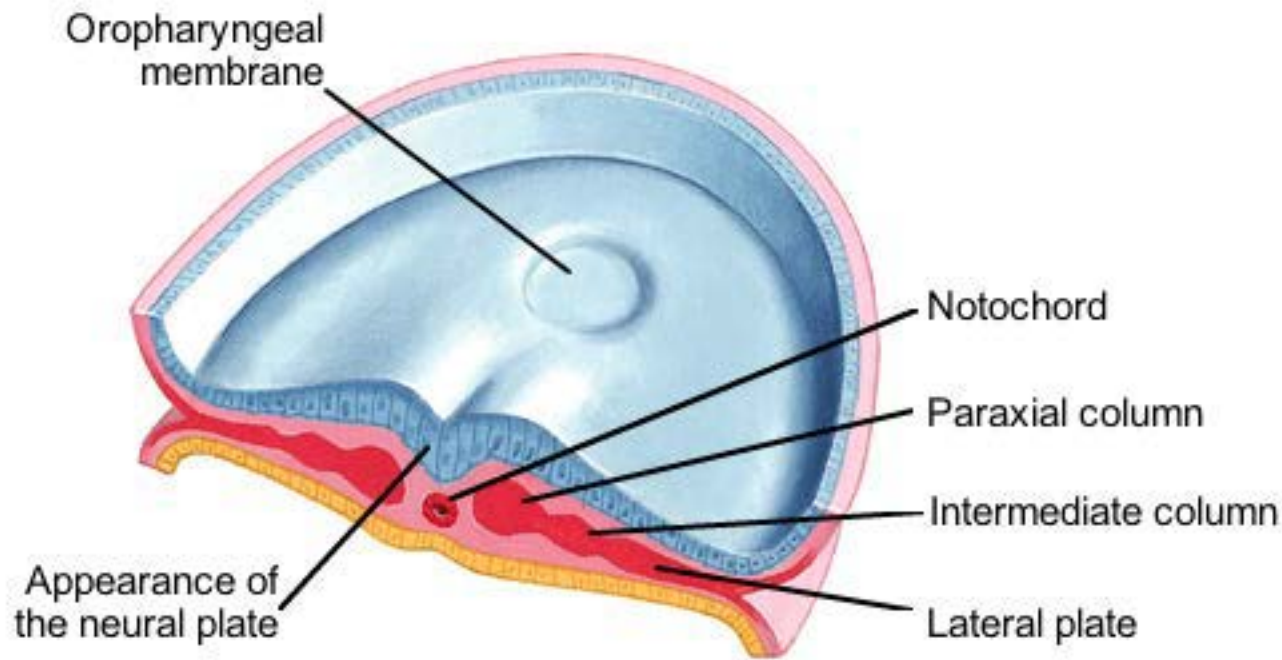
Birth



Secondary gyri are present; brain is 25% of its adult size.

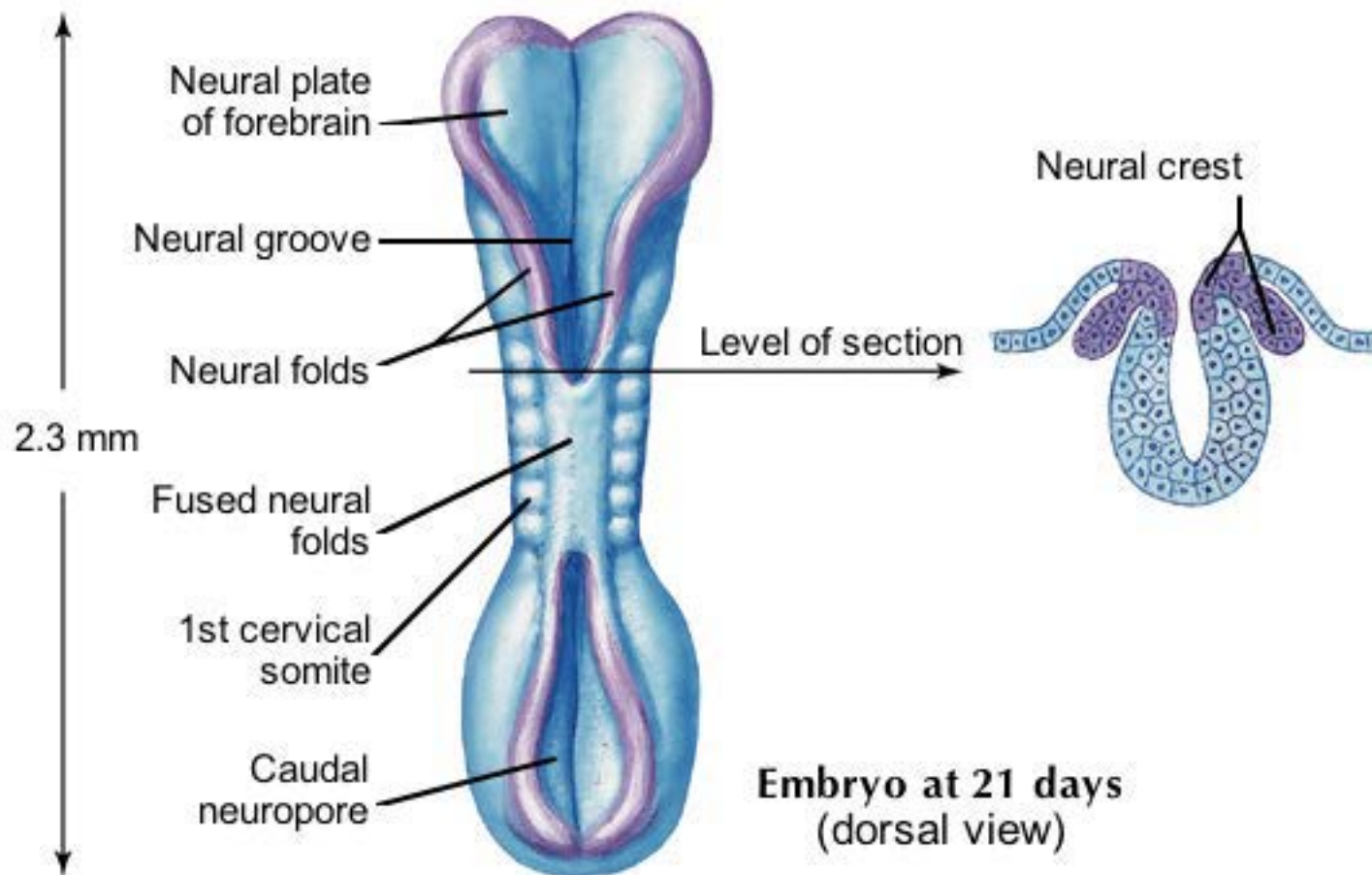
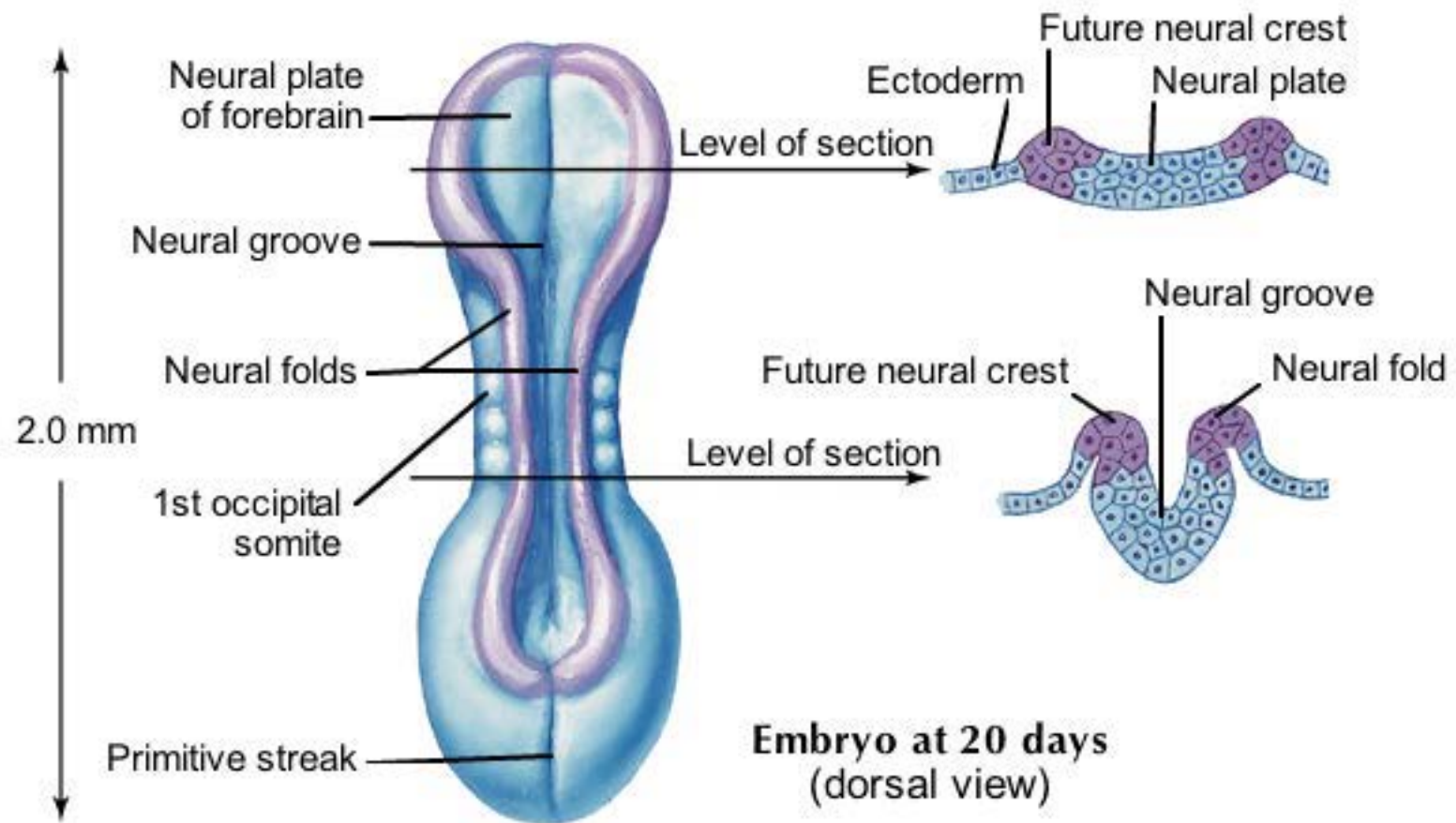


# Formation of the Neural Plate



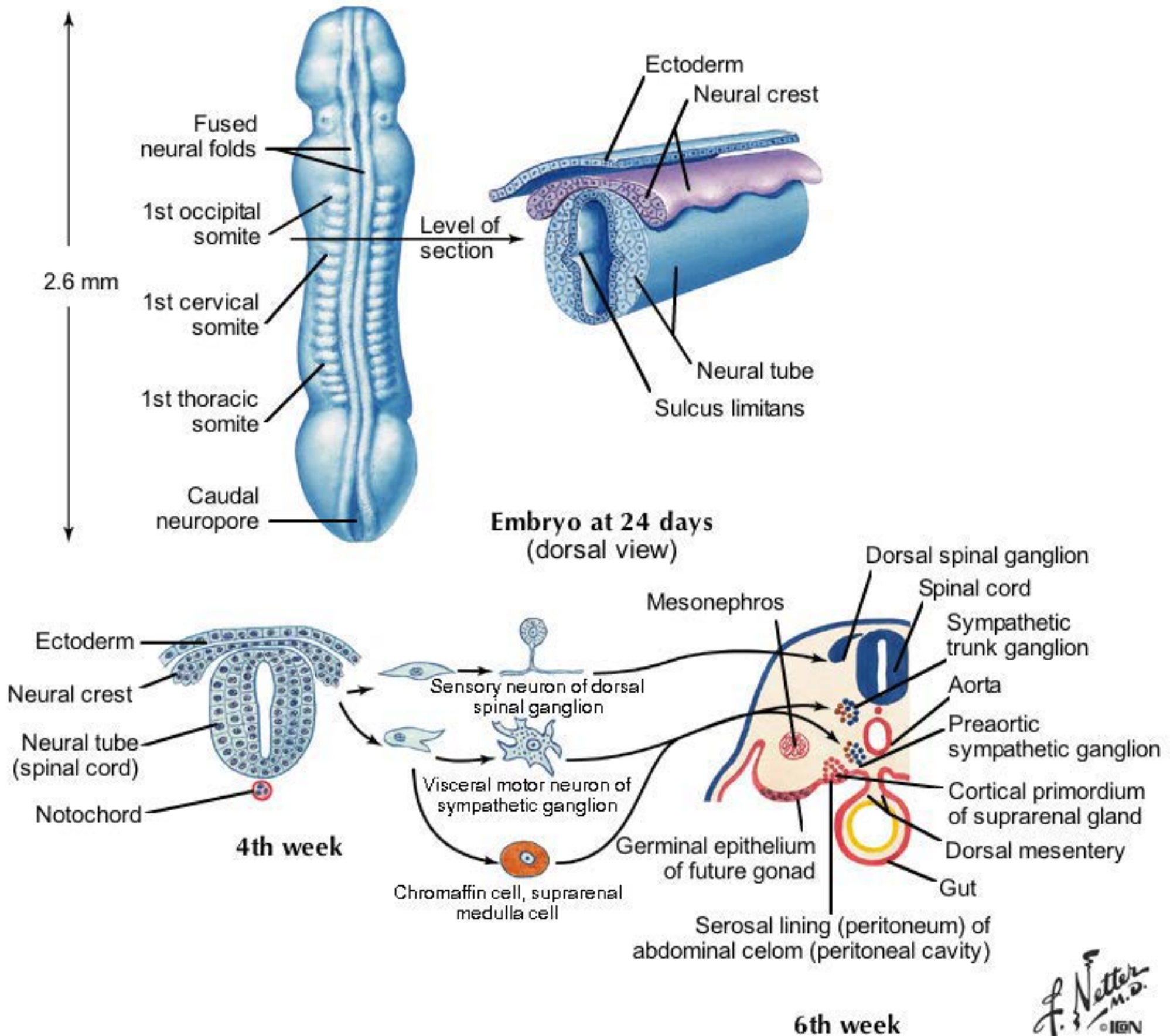
**Developmental fates of local regions of ectoderm of embryonic disc at 18 days**

# Neurulation





# Neural Tube and Neural Crest



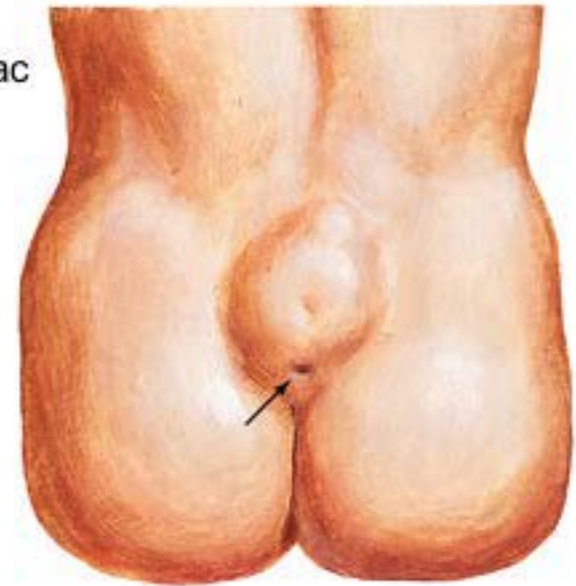
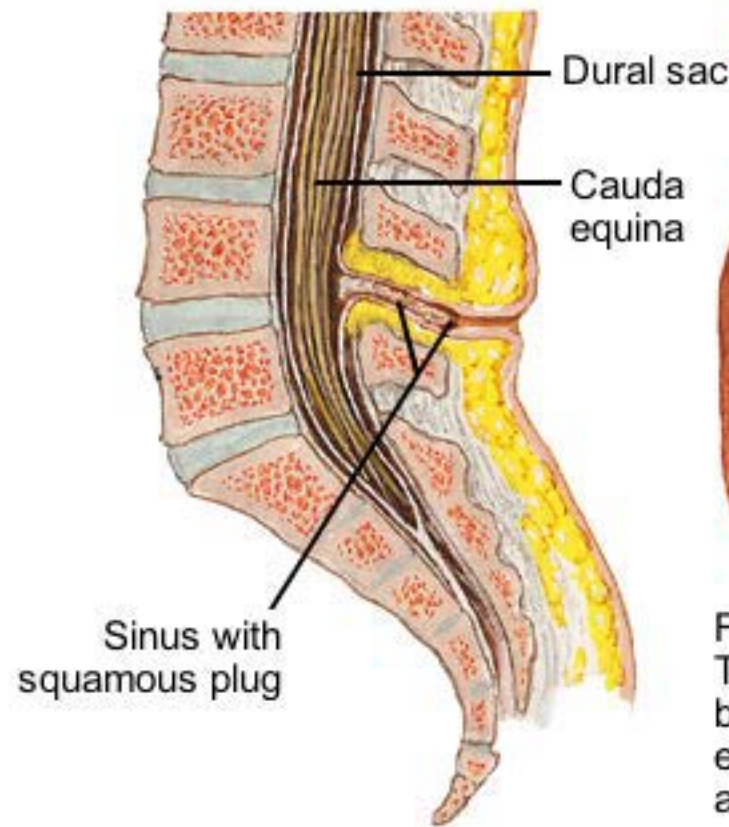


# Neural Tube Defects

## Spinal bifida occulta



## Dermal sinus

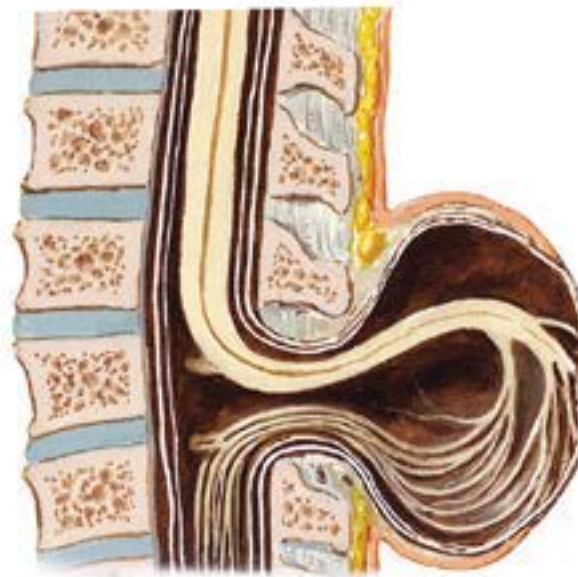


Fat pad overlying spina bifida occulta. Tuft of hair or only skin dimple may be present, or there may be no external manifestation. Dermal sinus also present in this case (arrow)

## Types of spina bifida aperta with protrusion of spinal contents



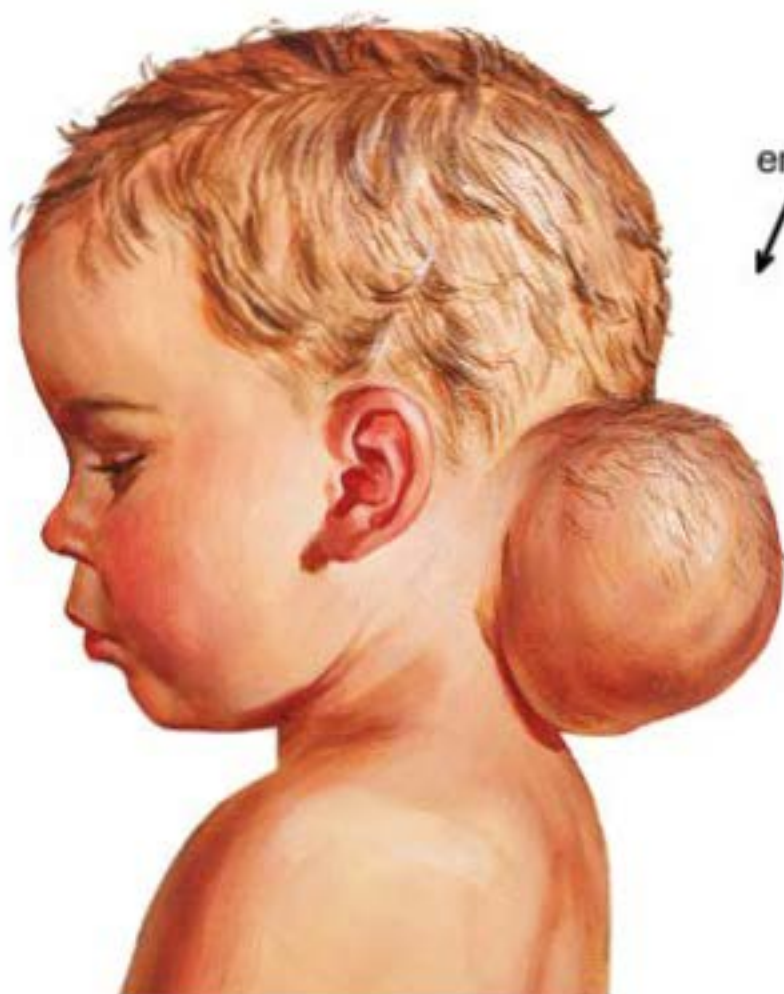
Meningocele



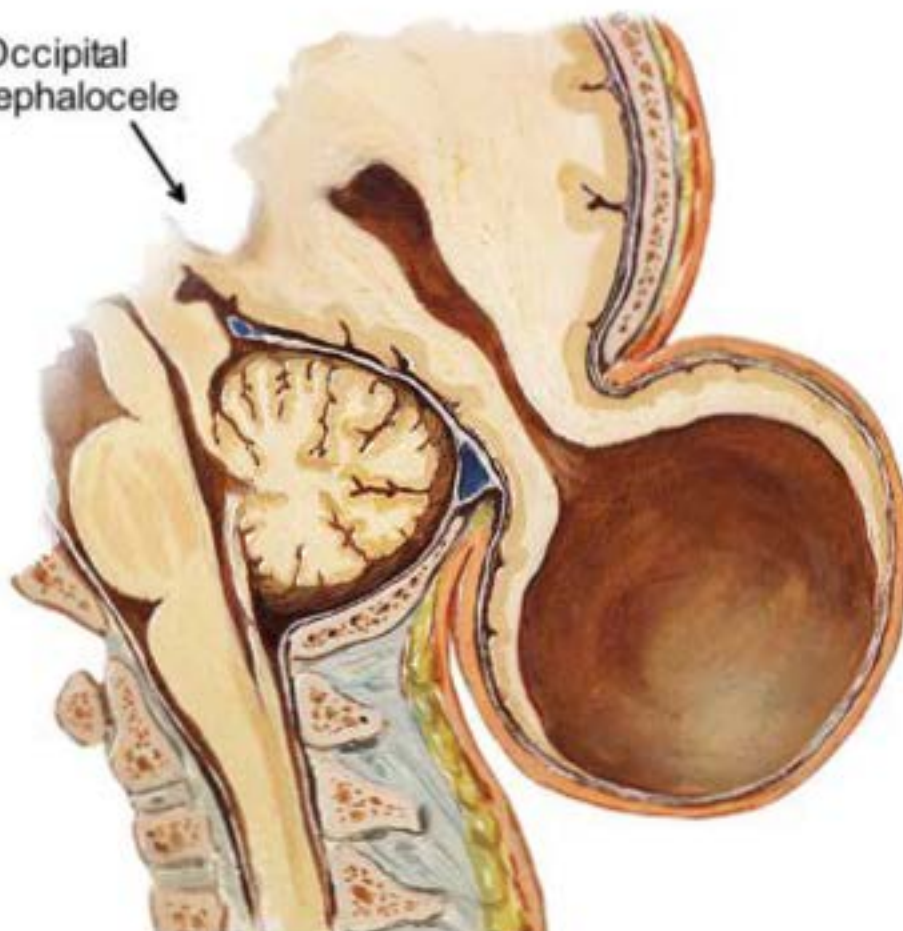
Meningomyelocele



# Neural Tube Defects



Occipital  
encephalocele



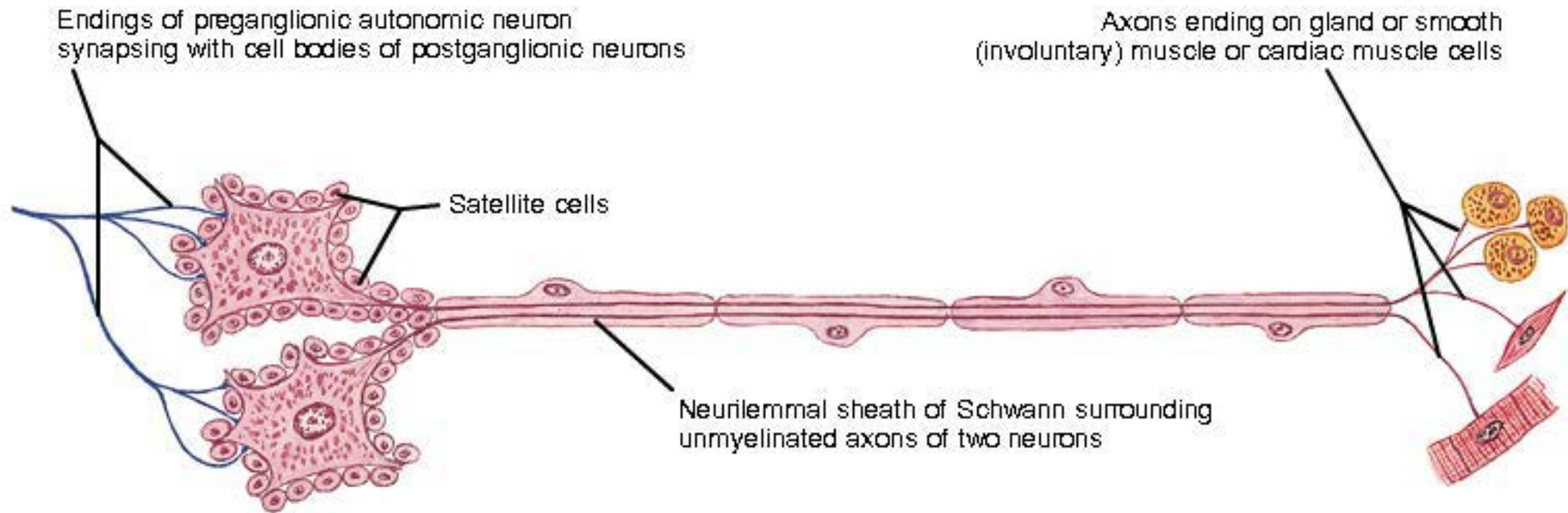
Frontal encephalocele



Anencephaly

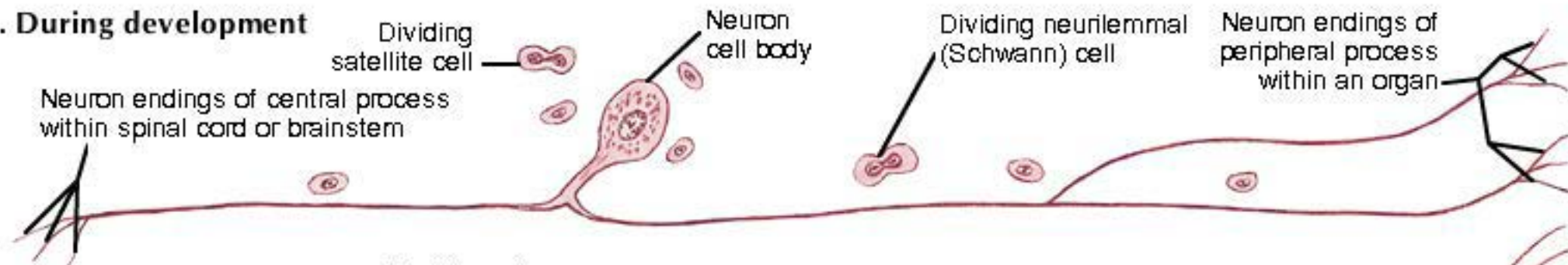
# Neuron Development

## Two postganglionic autonomic neurons of a sympathetic or parasympathetic ganglion

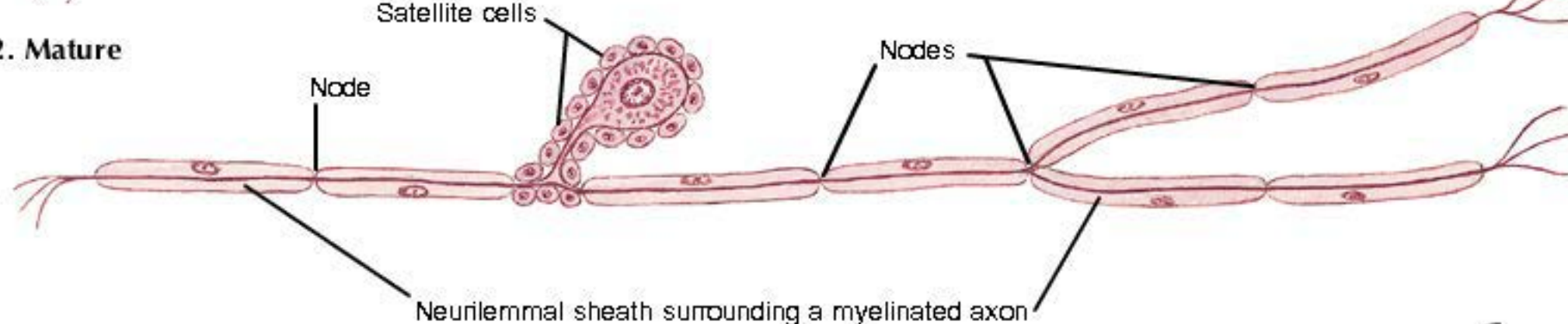


## Somatic or visceral sensory neuron of a spinal ganglion or sensory ganglion of cranial nerves V, VII, IX, or X

### 1. During development



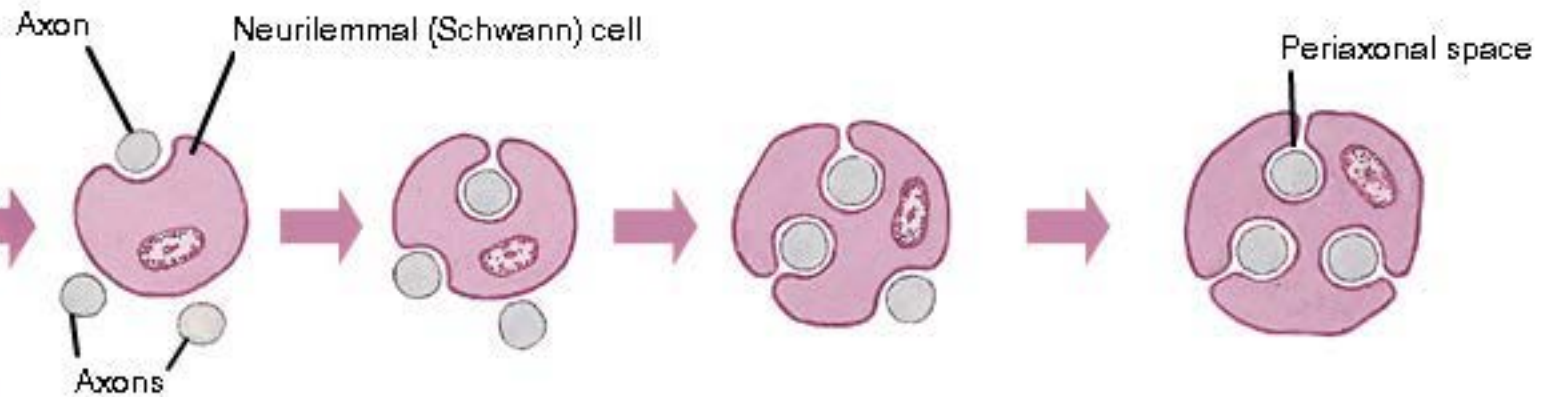
### 2. Mature



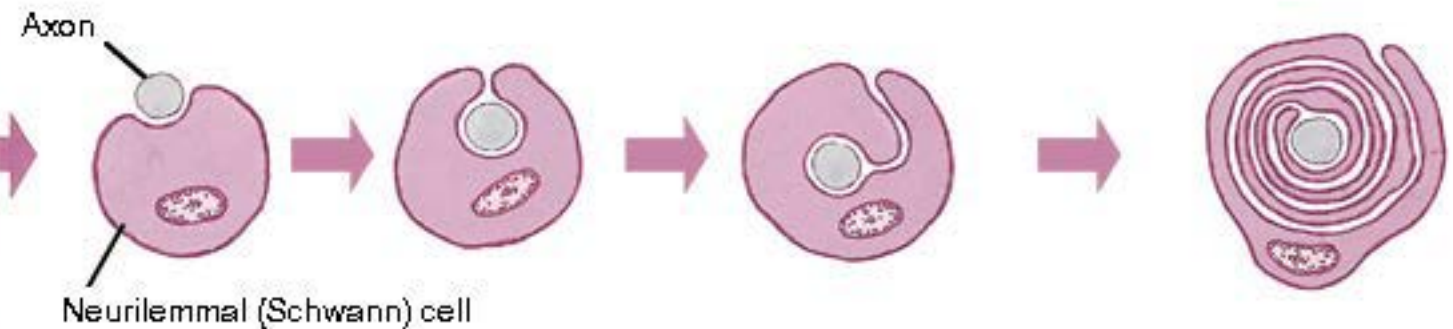


# Development of the Cellular Sheath of Axons

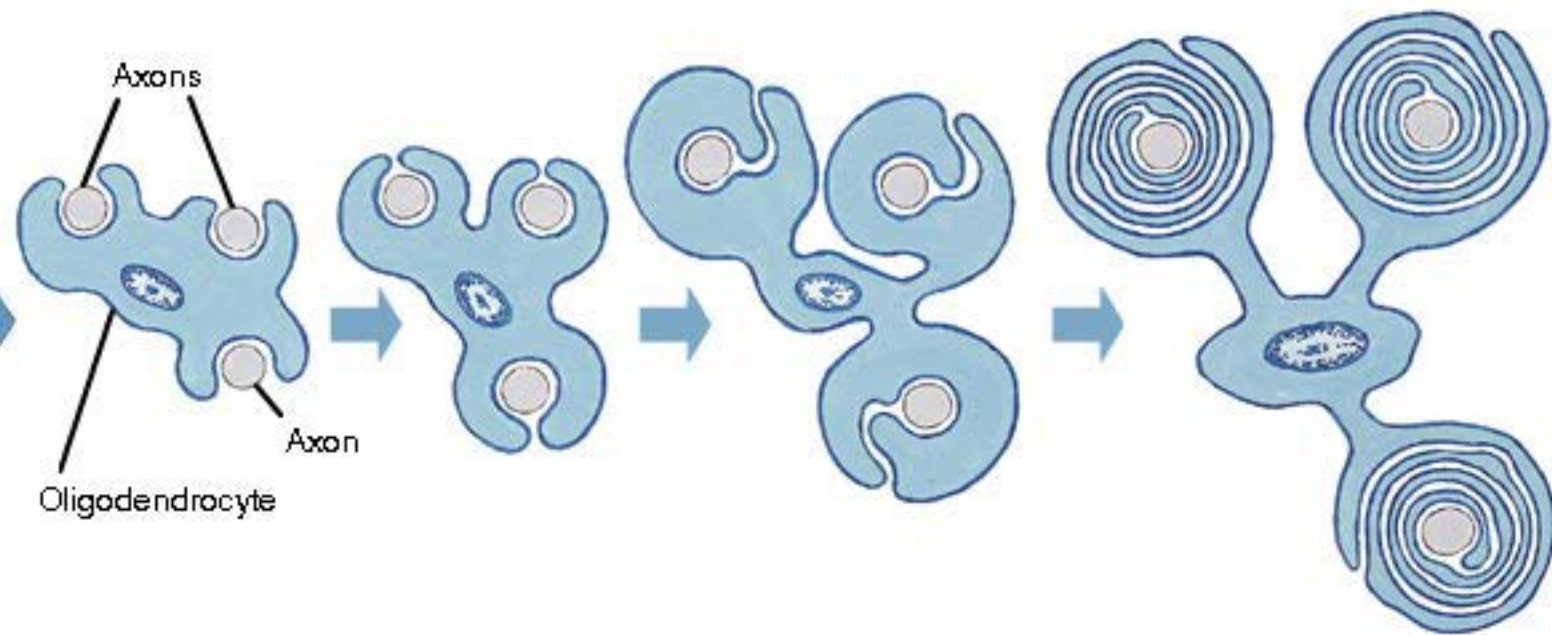
**Unmyelinated axons of peripheral neurons**  
(sensory, somatic motor, or visceral motor) being surrounded by cytoplasm of a neurilemmal (Schwann) cell



**Myelinated axon of peripheral neuron**  
(sensory, somatic motor, or visceral motor) being surrounded by a wrapping of cell membrane of a neurilemmal (Schwann) cell

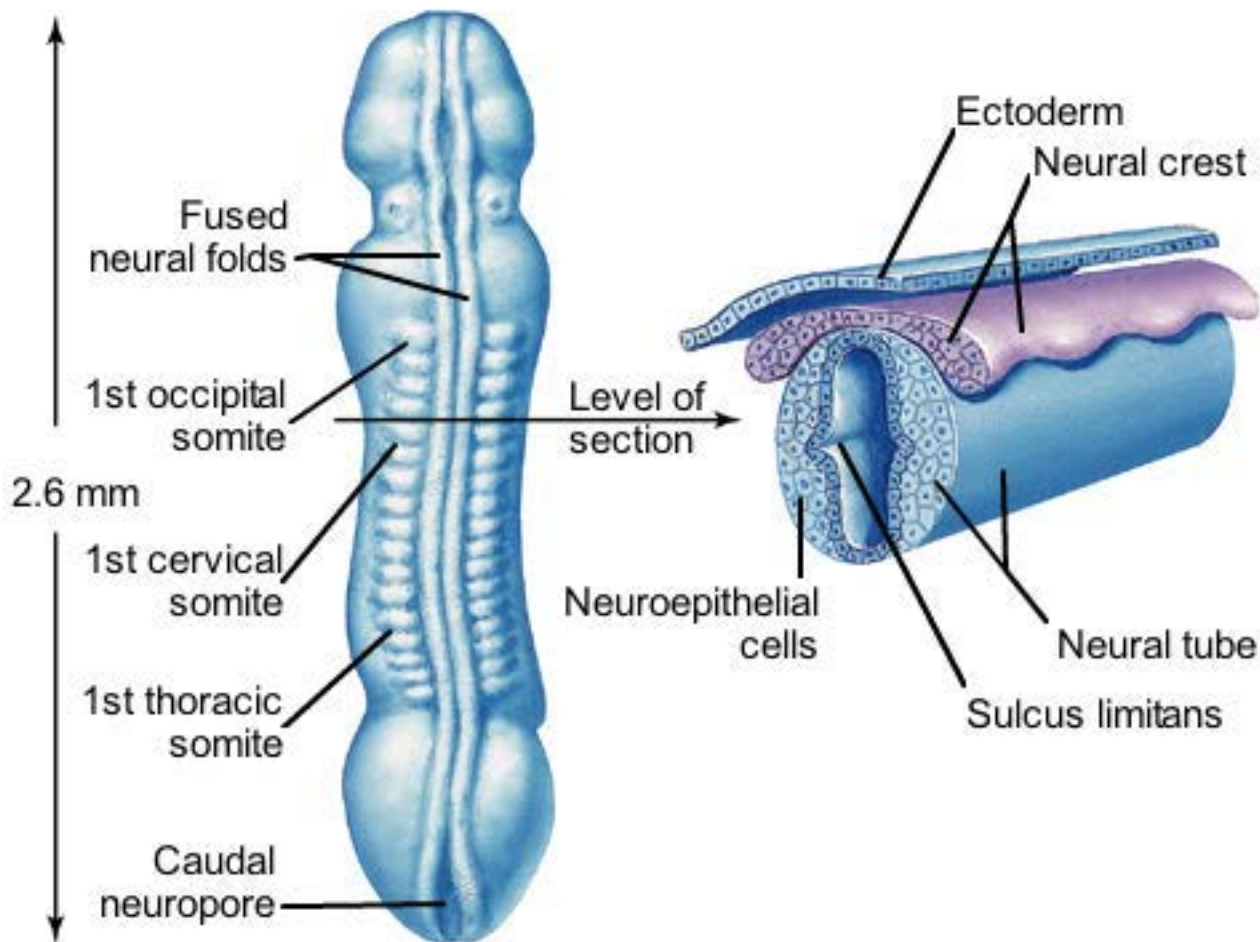


**Myelinated axon of CNS neurons** being surrounded by a wrapping of cell membrane of an oligodendrocyte.  
**Unmyelinated axons of CNS neurons** surrounded by cytoplasm of an oligodendrocyte in manner shown for neurilemmal cell in A



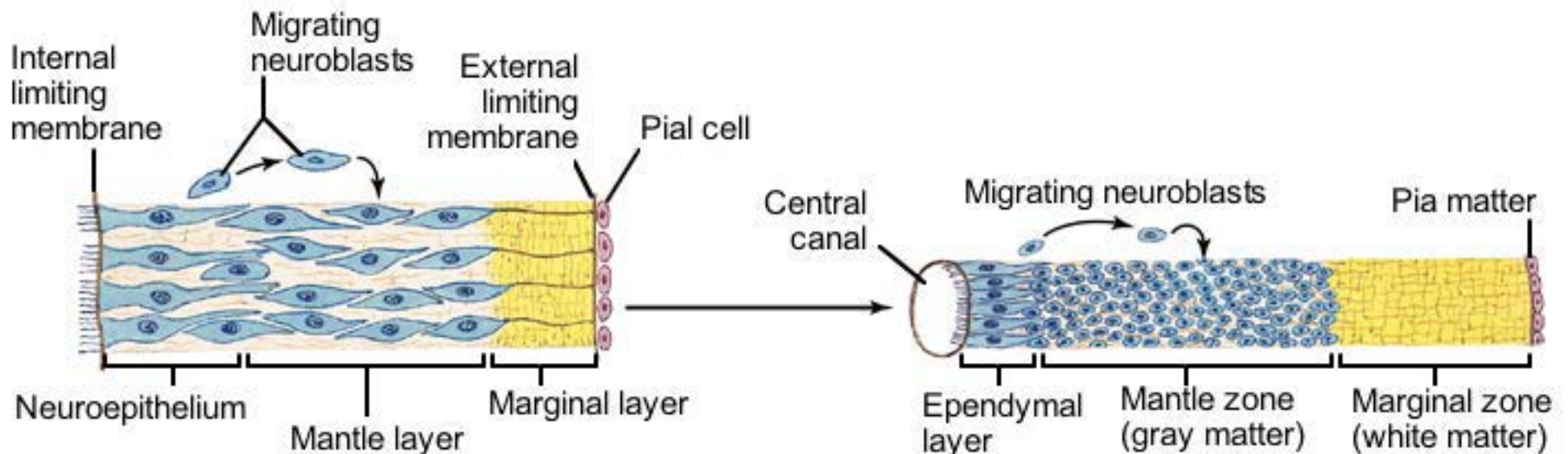
# Development of the Spinal Cord Layers

Embryo at 24 days (dorsal view)



*F. Netter M.D.*  
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Development of the neural tube layers in the spinal cord



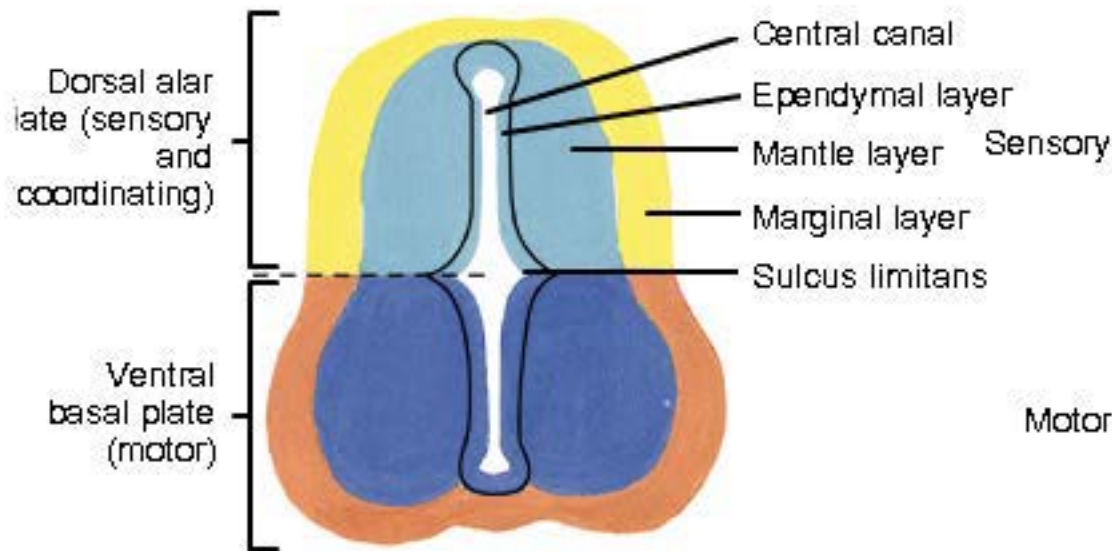
Neural tube at 5 weeks

Spinal cord at 3 months

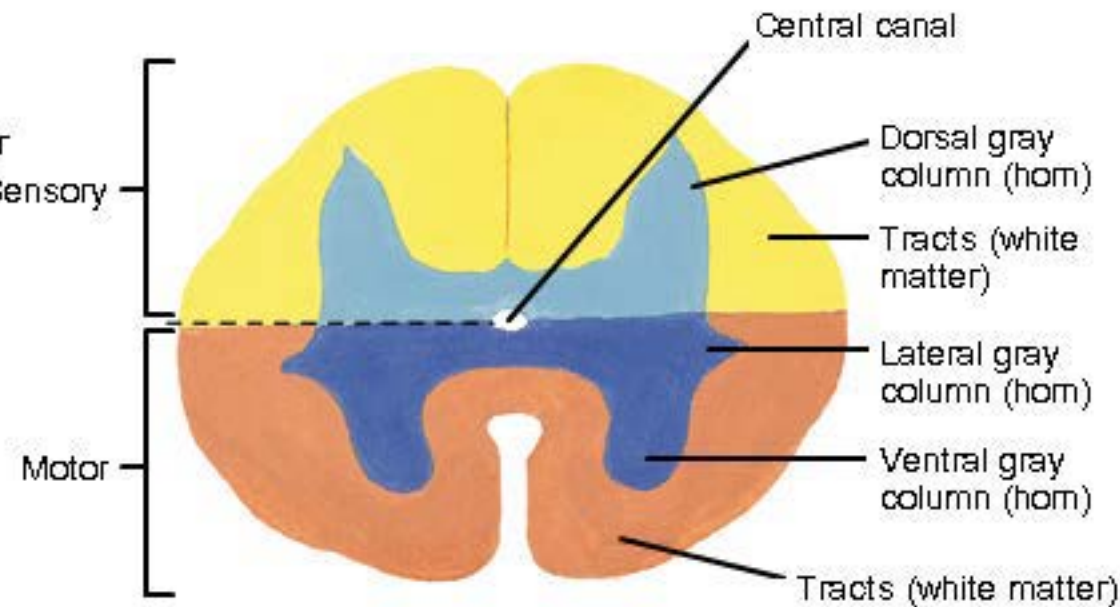


# Development of the Spinal Cord

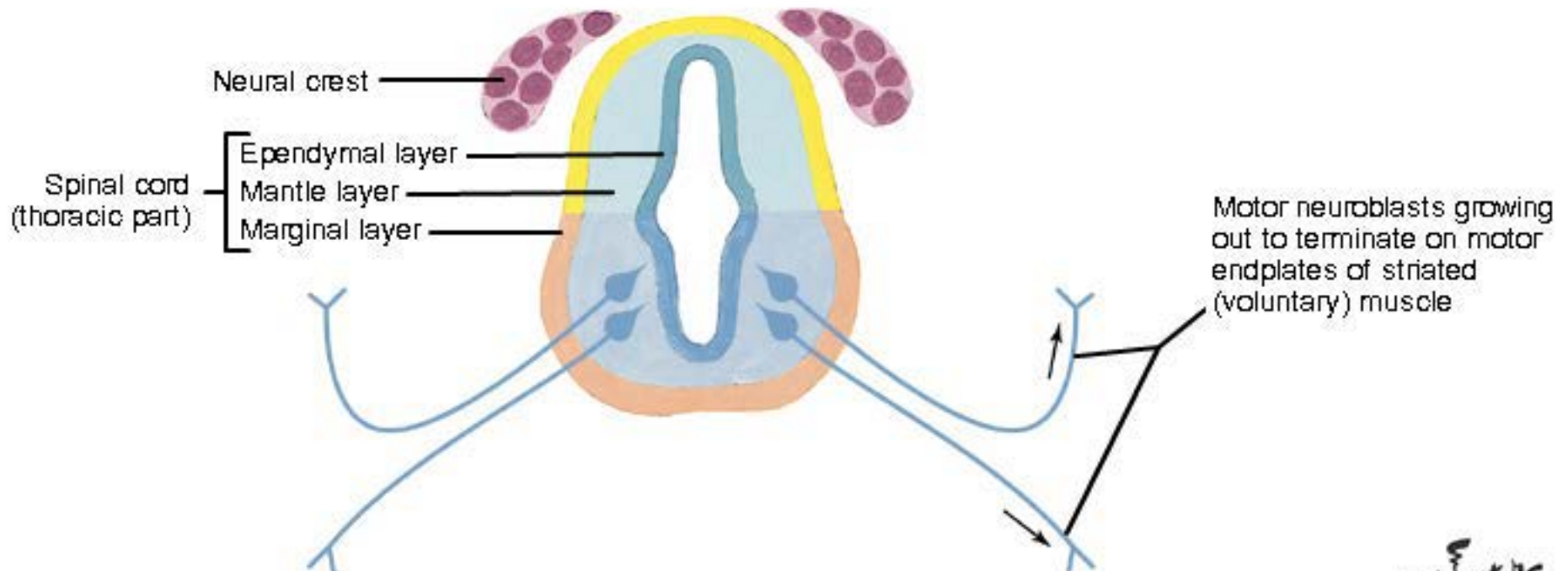
5 1/2 weeks (transverse section)



Mature (transverse section)

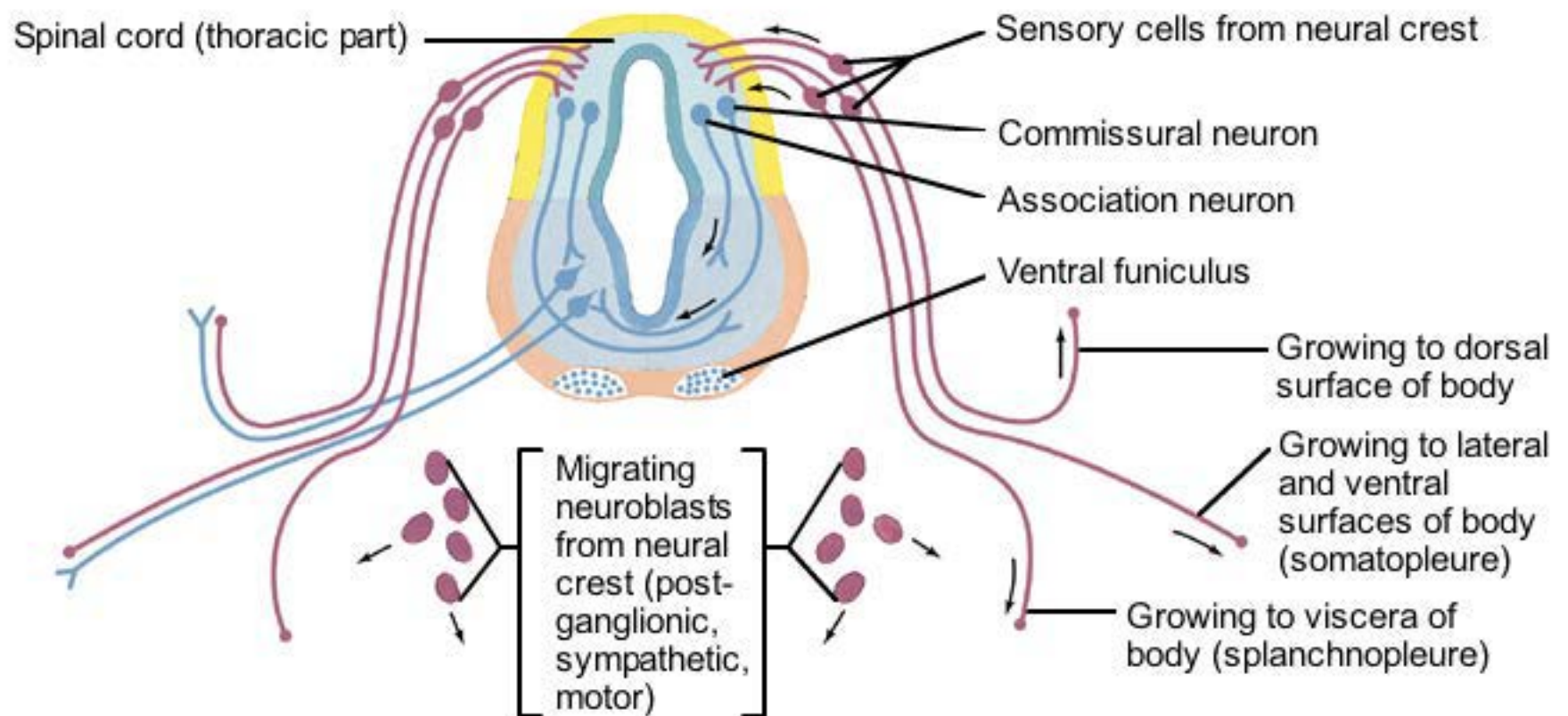


## Differentiation and growth of neurons at 26 days



# Peripheral Nervous System

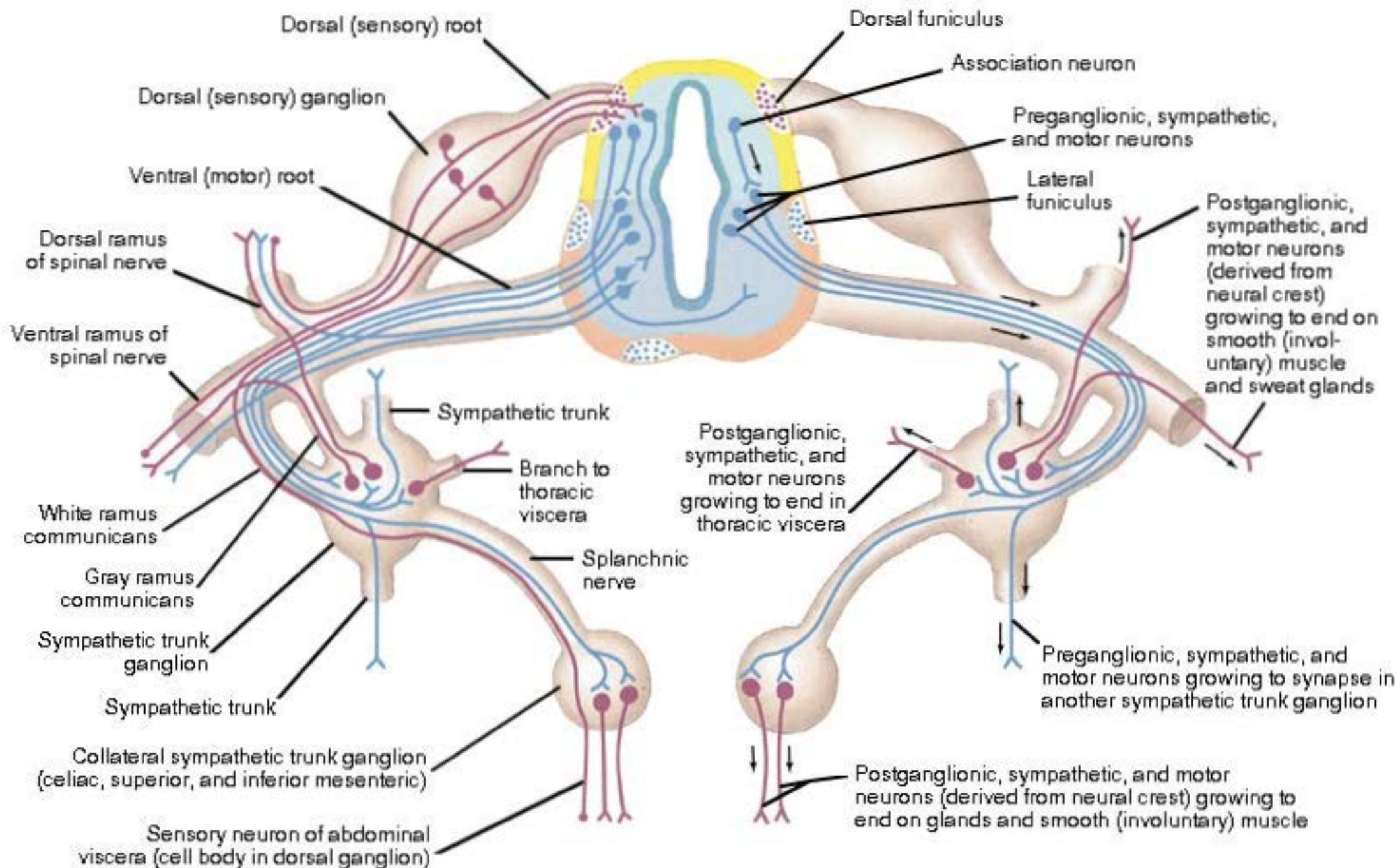
Differentiation and growth of neurons at 28 days  
(right side of diagram shows newly acquired neurons only)





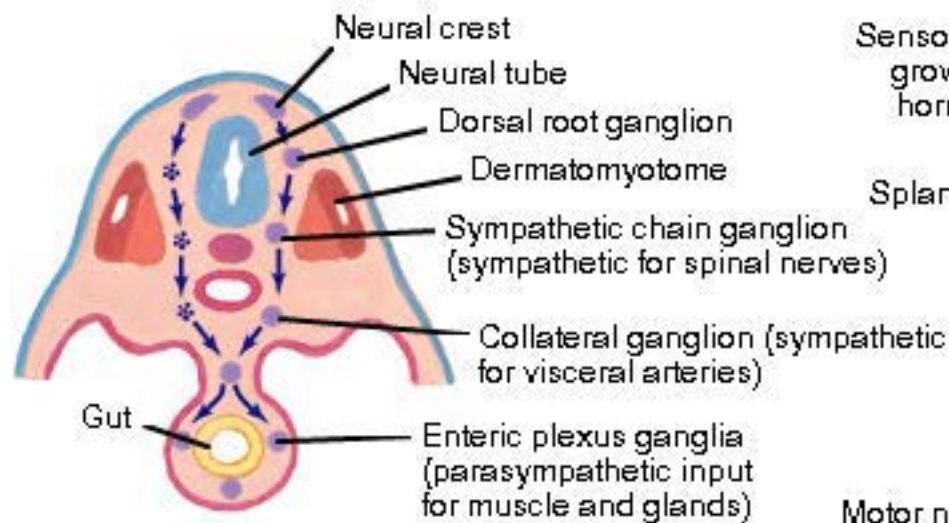
# Peripheral Nervous System

## Differentiation and growth of neurons at 5 to 7 weeks (right side of diagram shows neurons acquired since 28th day only)

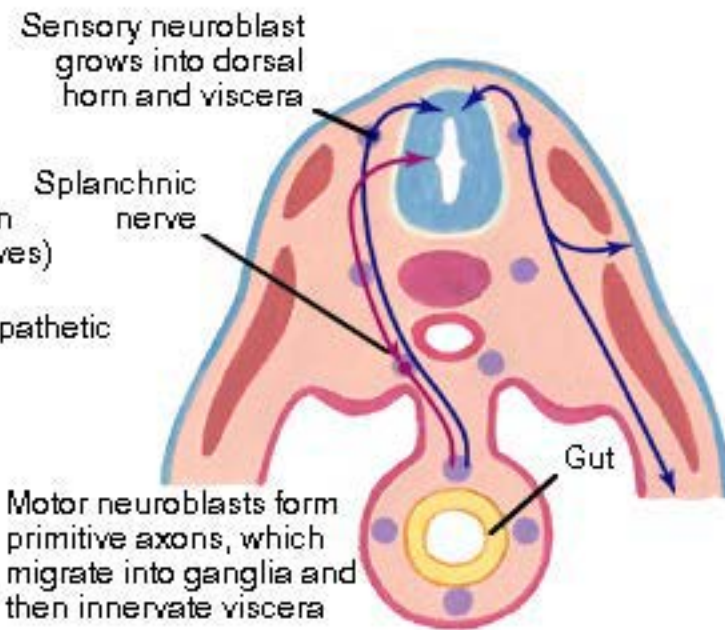




# Peripheral Nervous System

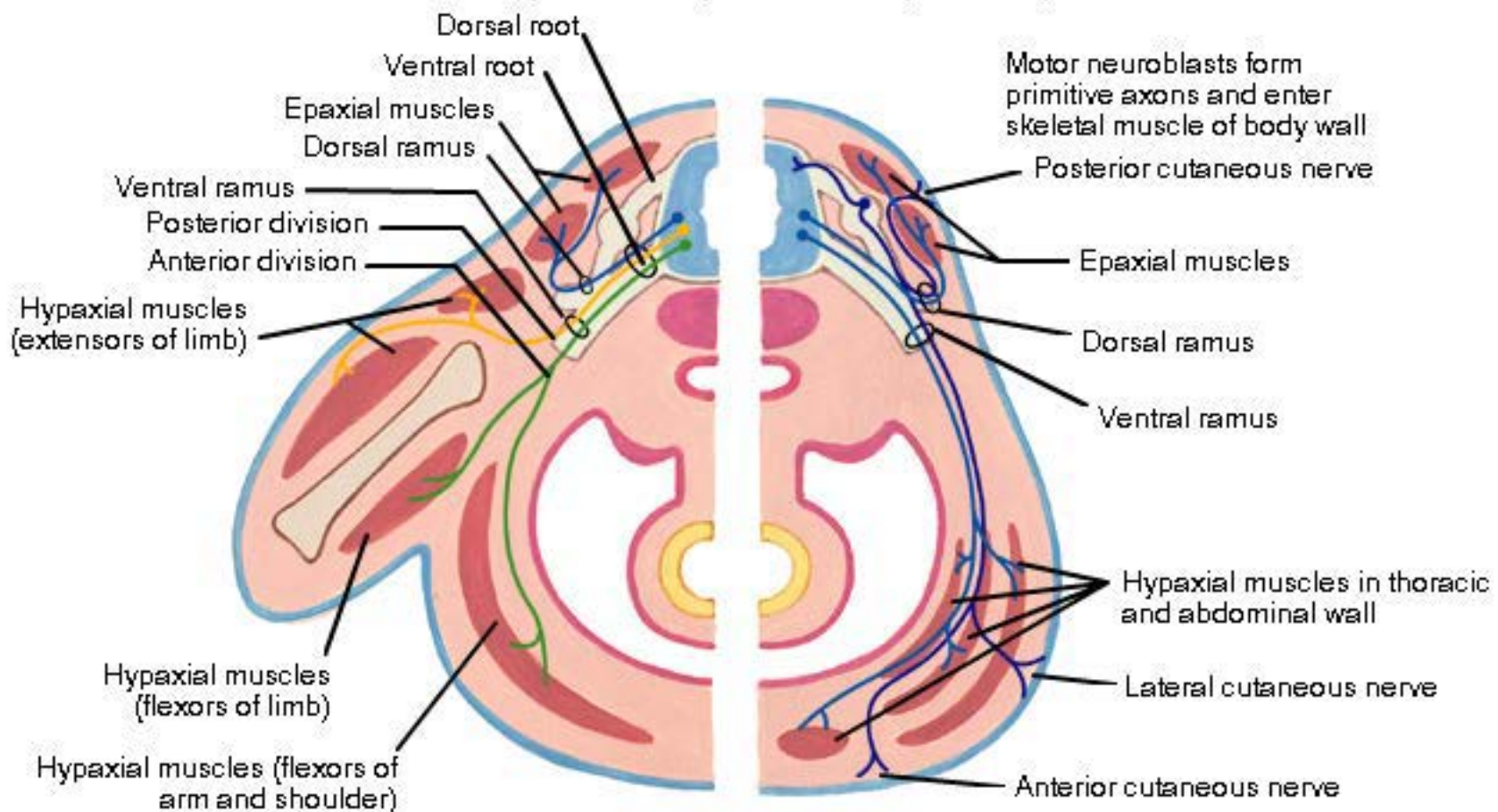


Migration of neural crest cells form peripheral ganglia of autonomic nervous system



## Autonomic Development

**Autonomic nervous system mostly innervates splanchnopleure (viscera)**

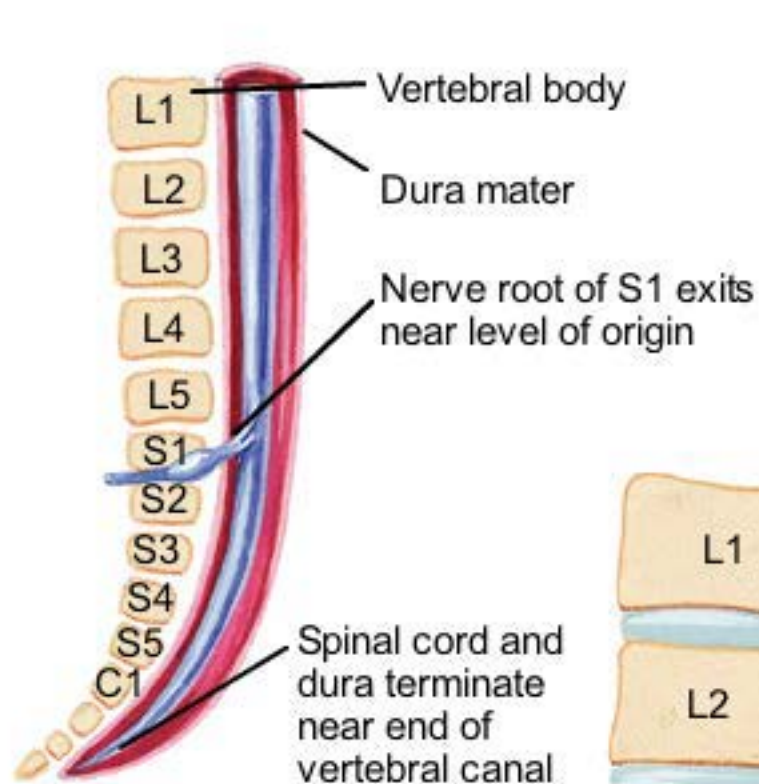


## Somatic Development

**Somatic nervous system innervates somatopleure (body wall)**

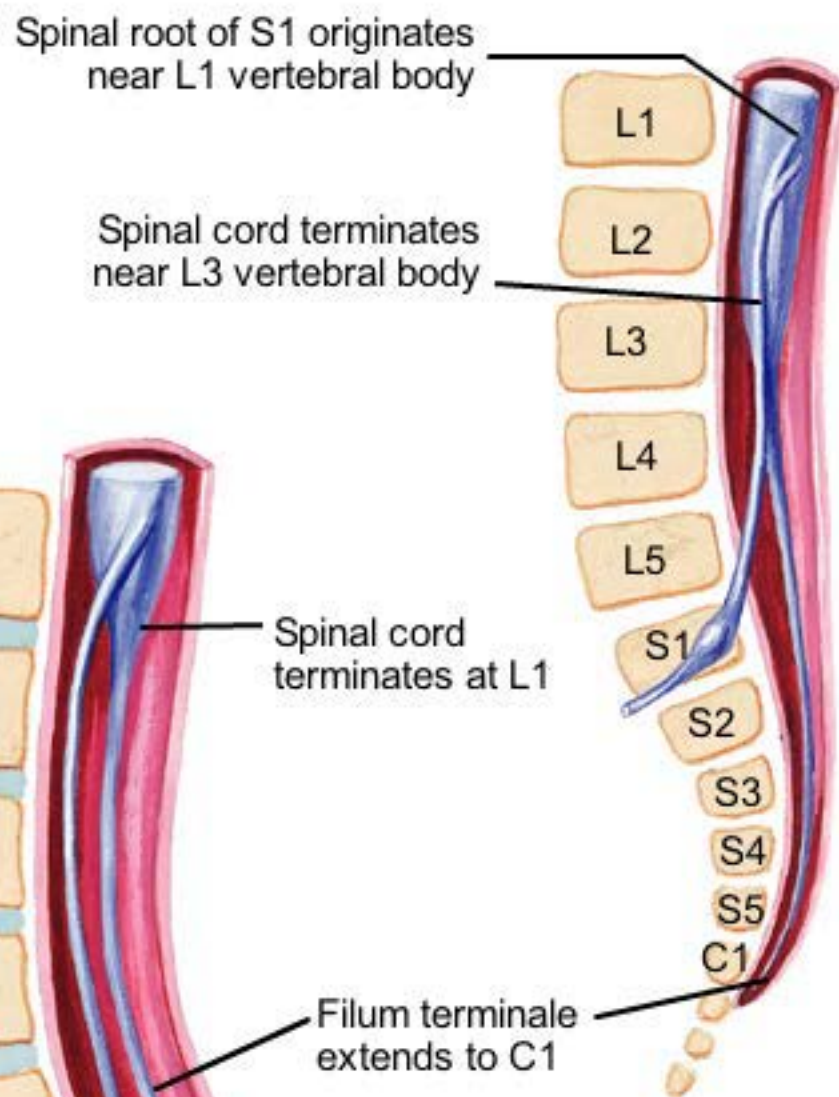


# Growth of the Spinal Cord and Vertebral Column

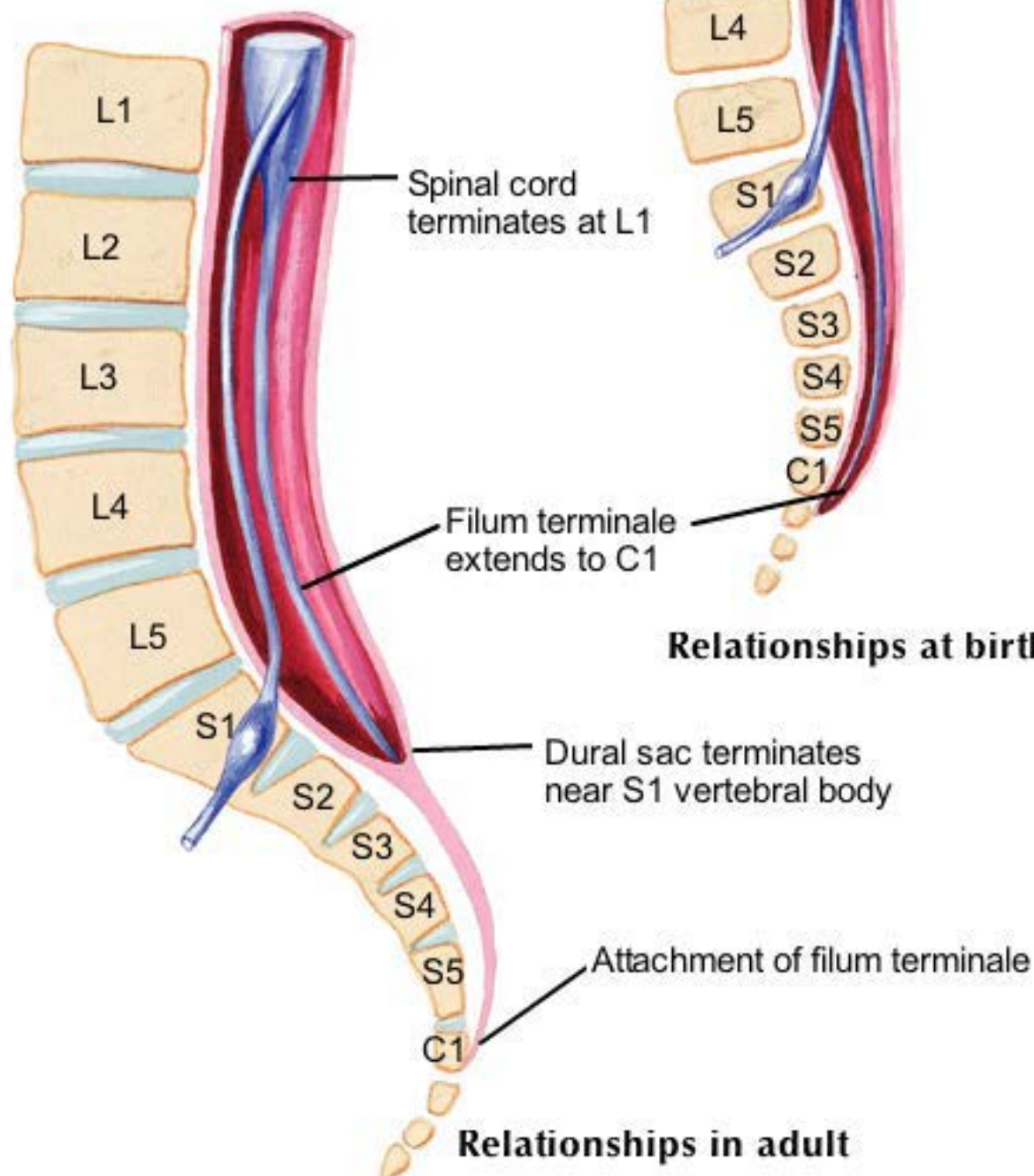


**Relationships in fetus at 2–3 months**

Nerve root of spinal nerve S1 must travel from level of L1 vertebral body to exit at S1 vertebral level



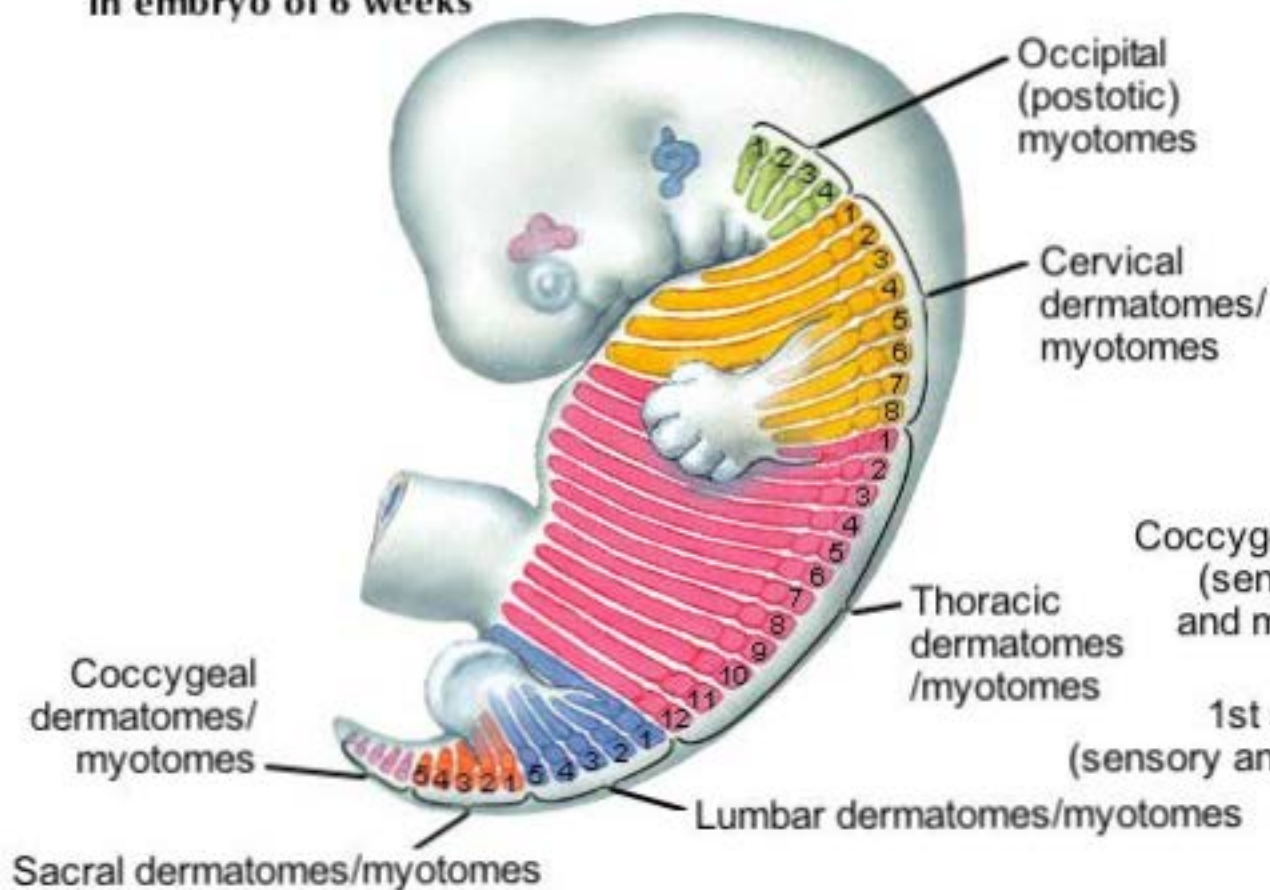
**Relationships at birth**



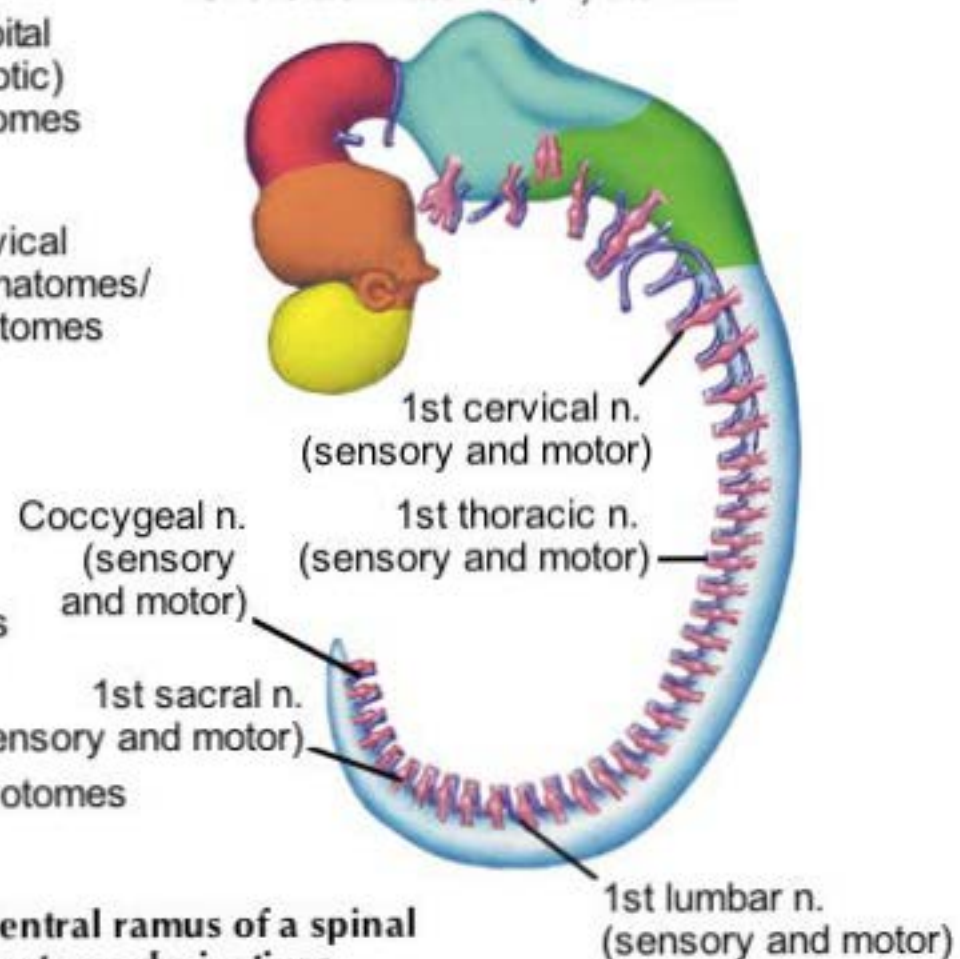
**Relationships in adult**

# Embryonic Dermatomes

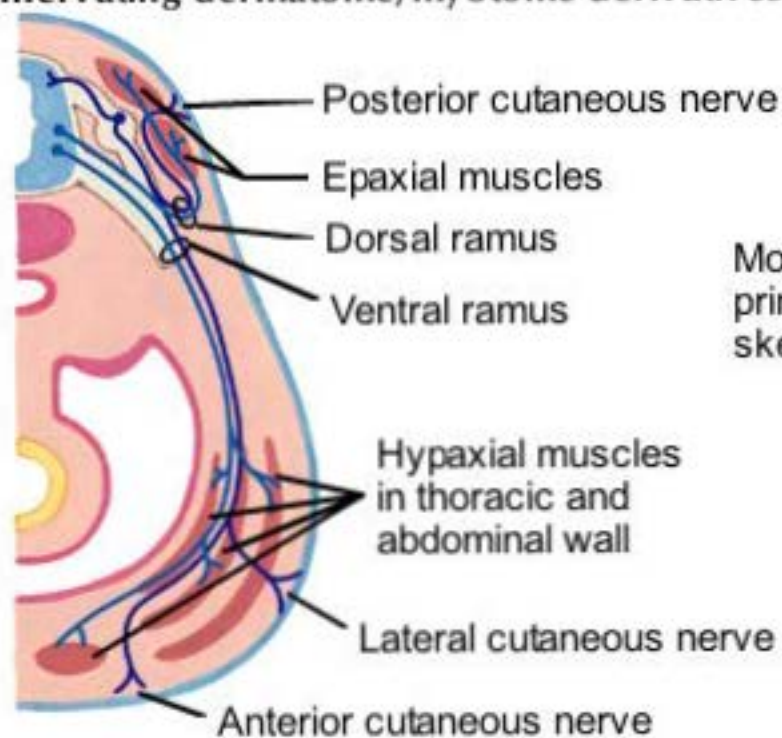
Segmental distribution of dermatomes/myotomes in embryo of 6 weeks



One pair of spinal nerves relates to each of the dermatomes/myotomes



Cross section of the dorsal and ventral ramus of a spinal nerve innervating dermatome/myotome derivatives

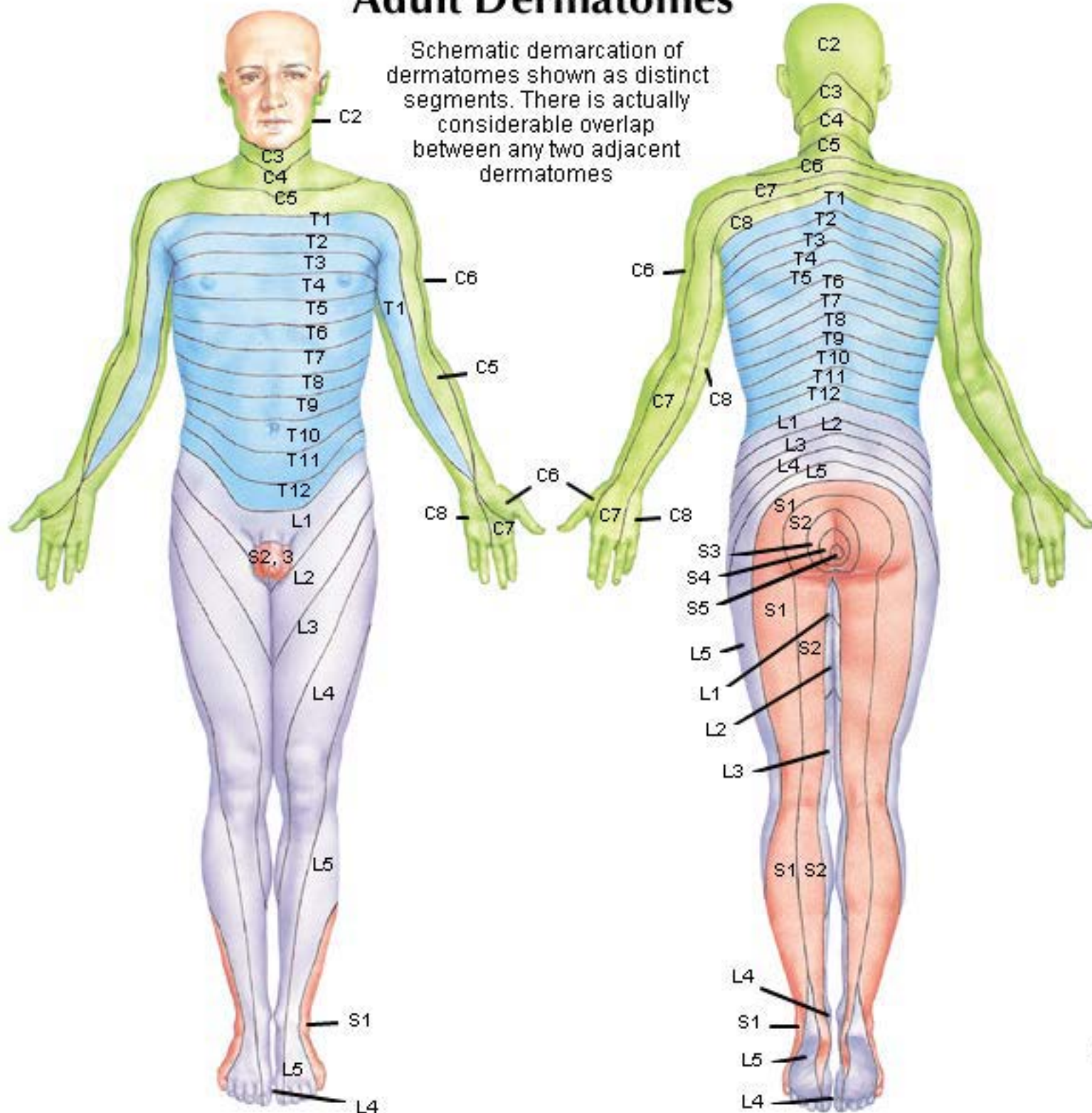


Motor neuroblasts form primitive axons and enter skeletal muscle of body wall



# Adult Dermatomes

Schematic demarcation of dermatomes shown as distinct segments. There is actually considerable overlap between any two adjacent dermatomes



## Levels of principal dermatomes

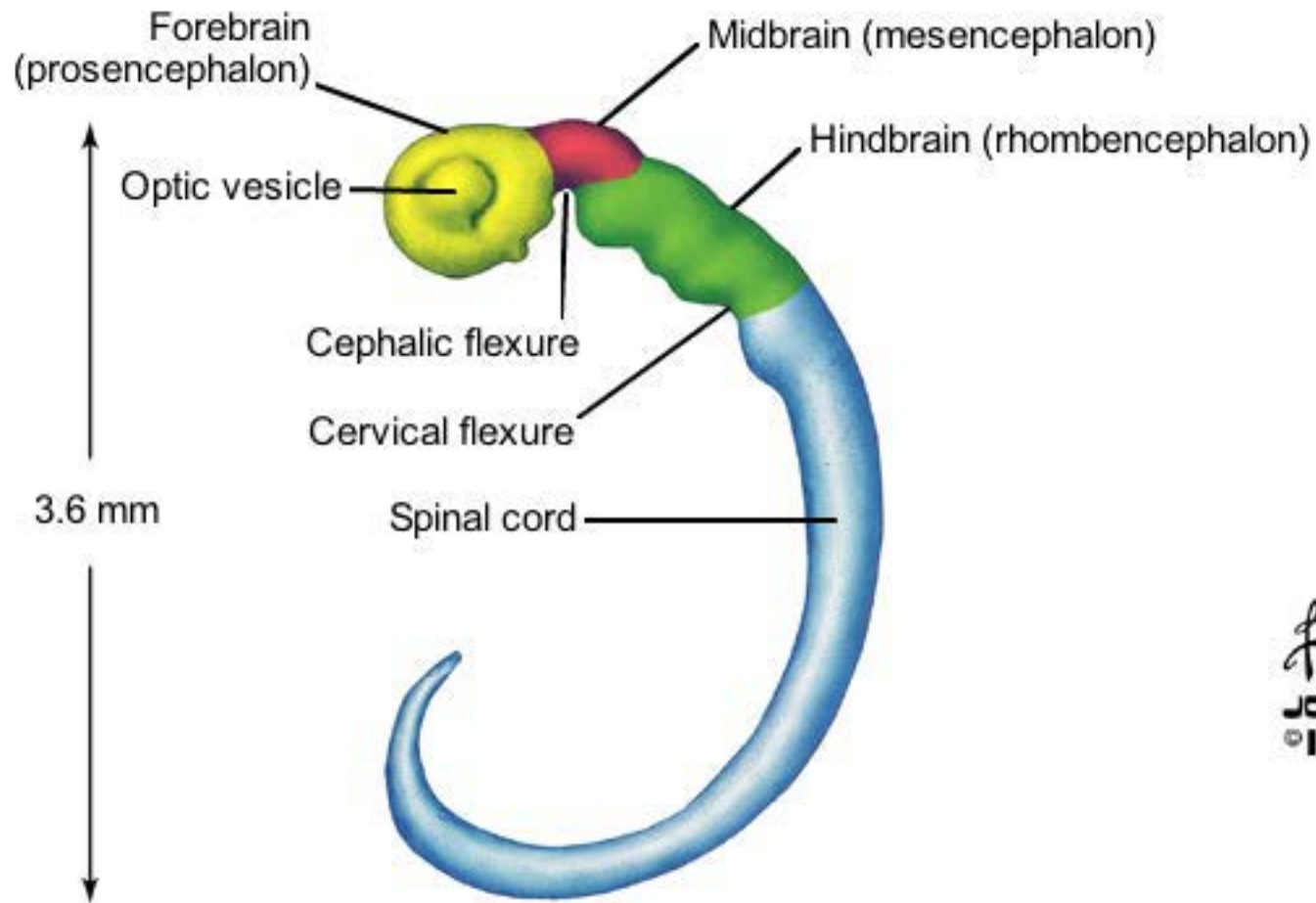
**C5** Clavicles  
**C5, 6, 7** Lateral parts of upper limbs  
**C8, T1** Medial sides of upper limbs  
**C6** Thumb  
**C6, 7, 8** Hand  
**C8** Ring and little fingers  
**T4** Level of nipples

**T10** Level of umbilicus  
**T12** Inguinal or groin regions  
**L1, 2, 3, 4** Anterior and inner surfaces of lower limbs  
**L4, 5, S1** Foot  
**L4** Medial side of great toe  
**S1, 2, L5** Posterior and outer surfaces of lower limbs  
**S1** Lateral margin of foot and little toe  
**S2, 3, 4** Perineum

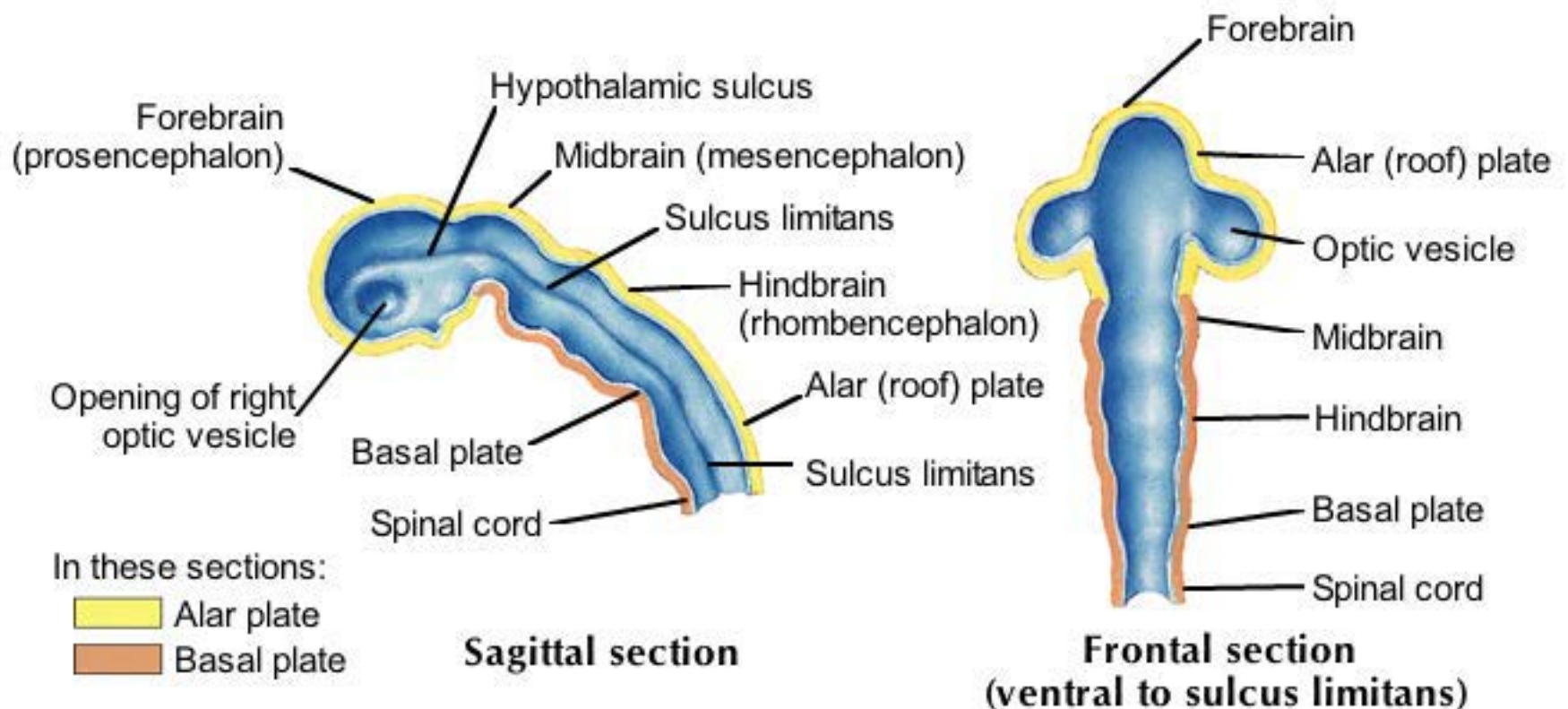
*F. Netter M.D.*  
 © IGV

# Development of the Brain

## Central nervous system at 28 days

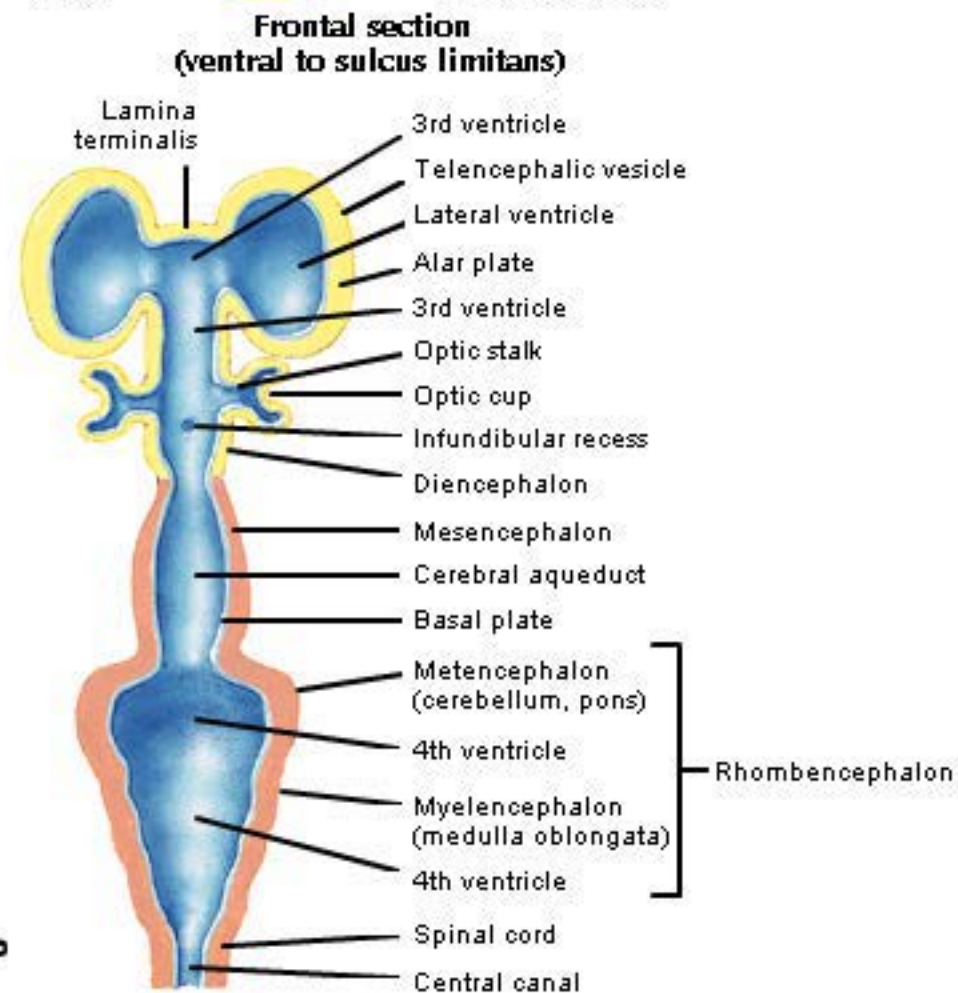
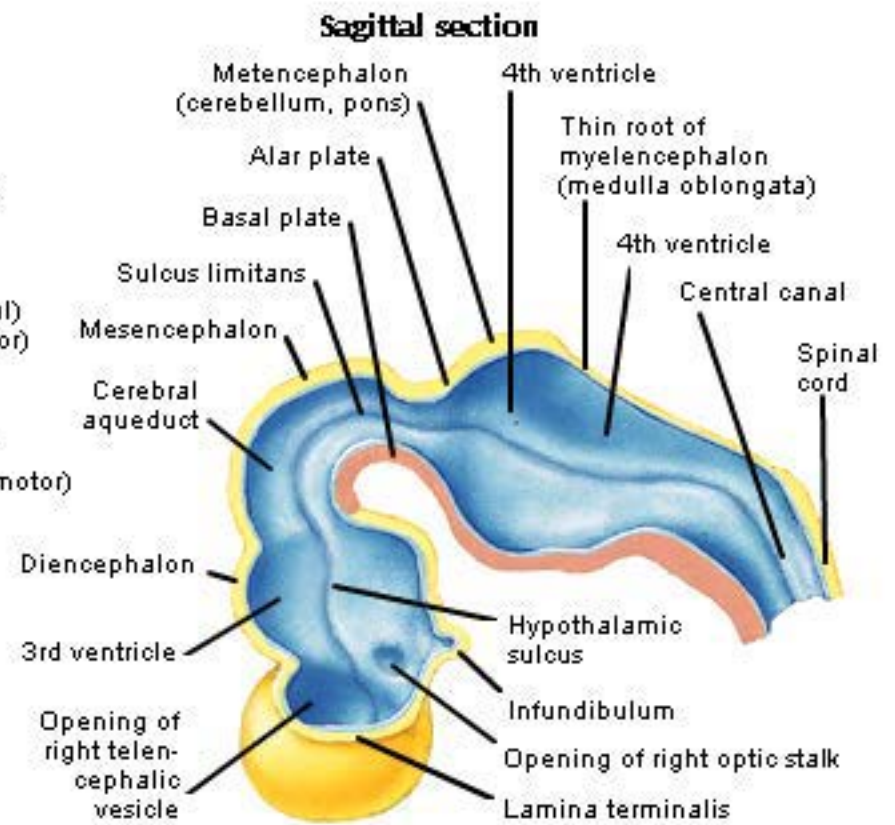
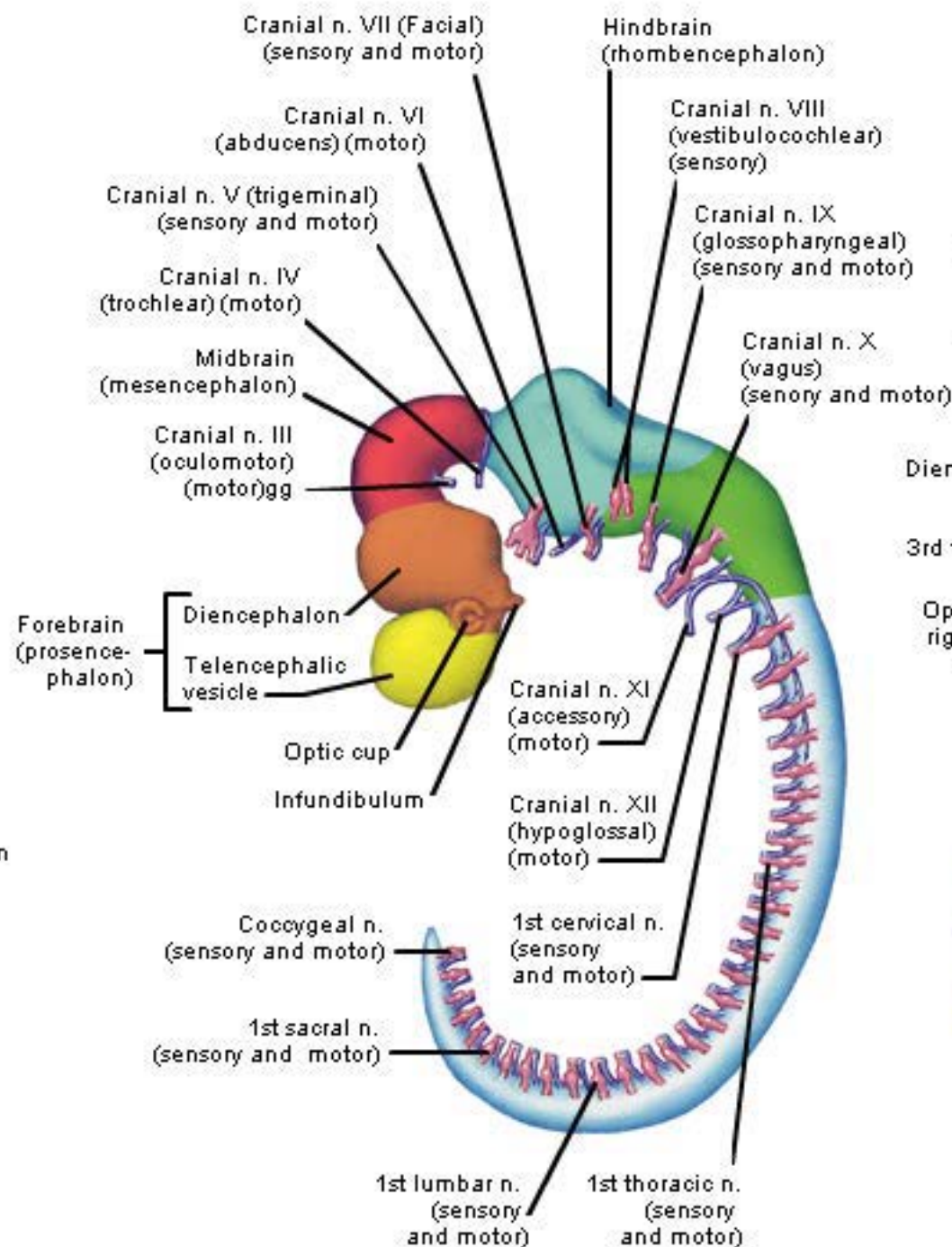


*F. Netter M.D.*  
**JOHN A. CRAIG M.D.**  
 © ION





# Development of the Brain

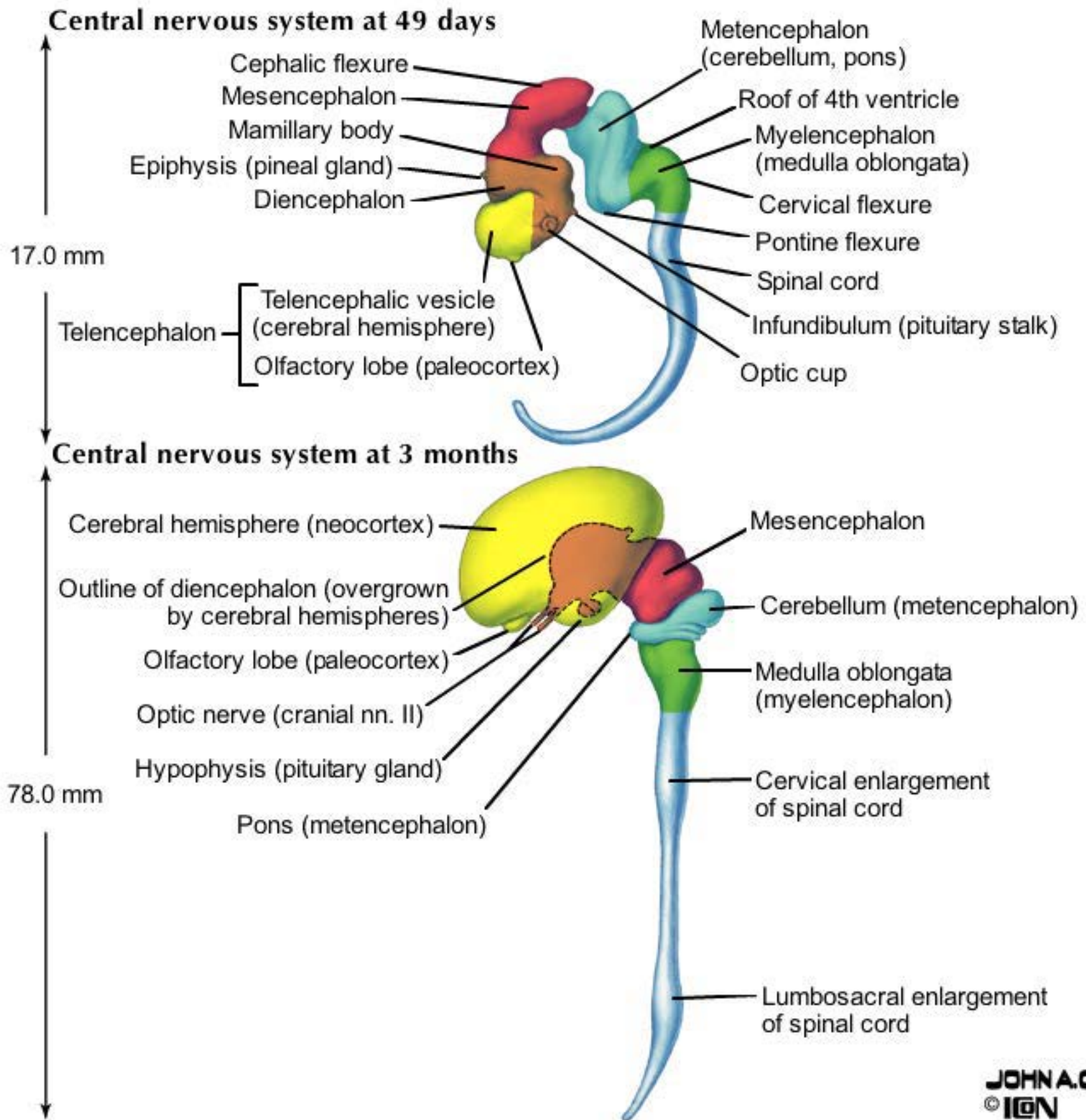


In sagittal and frontal sections:

- Alar (roof) plate
- Basal plate
- Derivatives of neural crest

*F. Netter M.D.*  
**JOHN A. CRAIG AND**  
**© IGM**

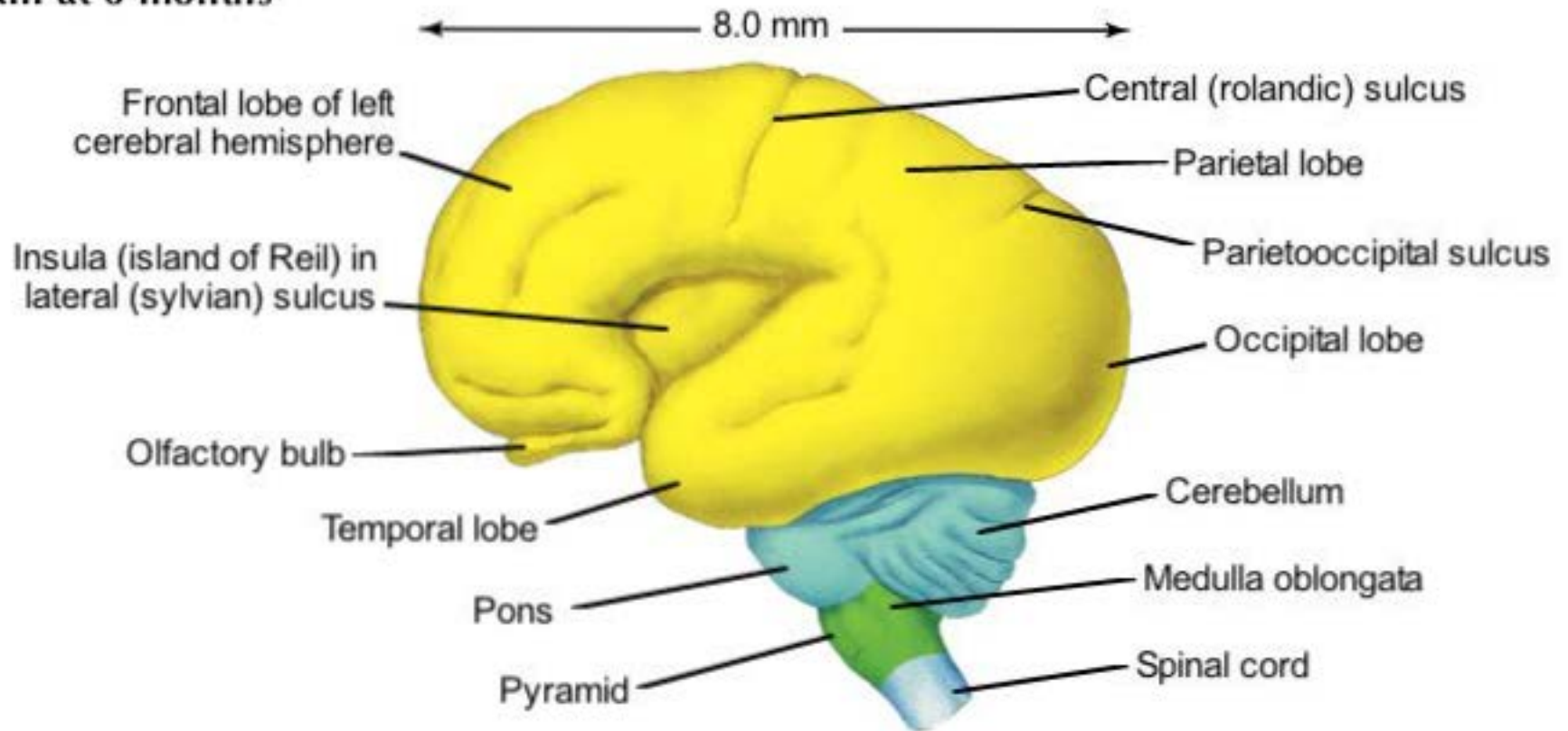
# Development of the Brain



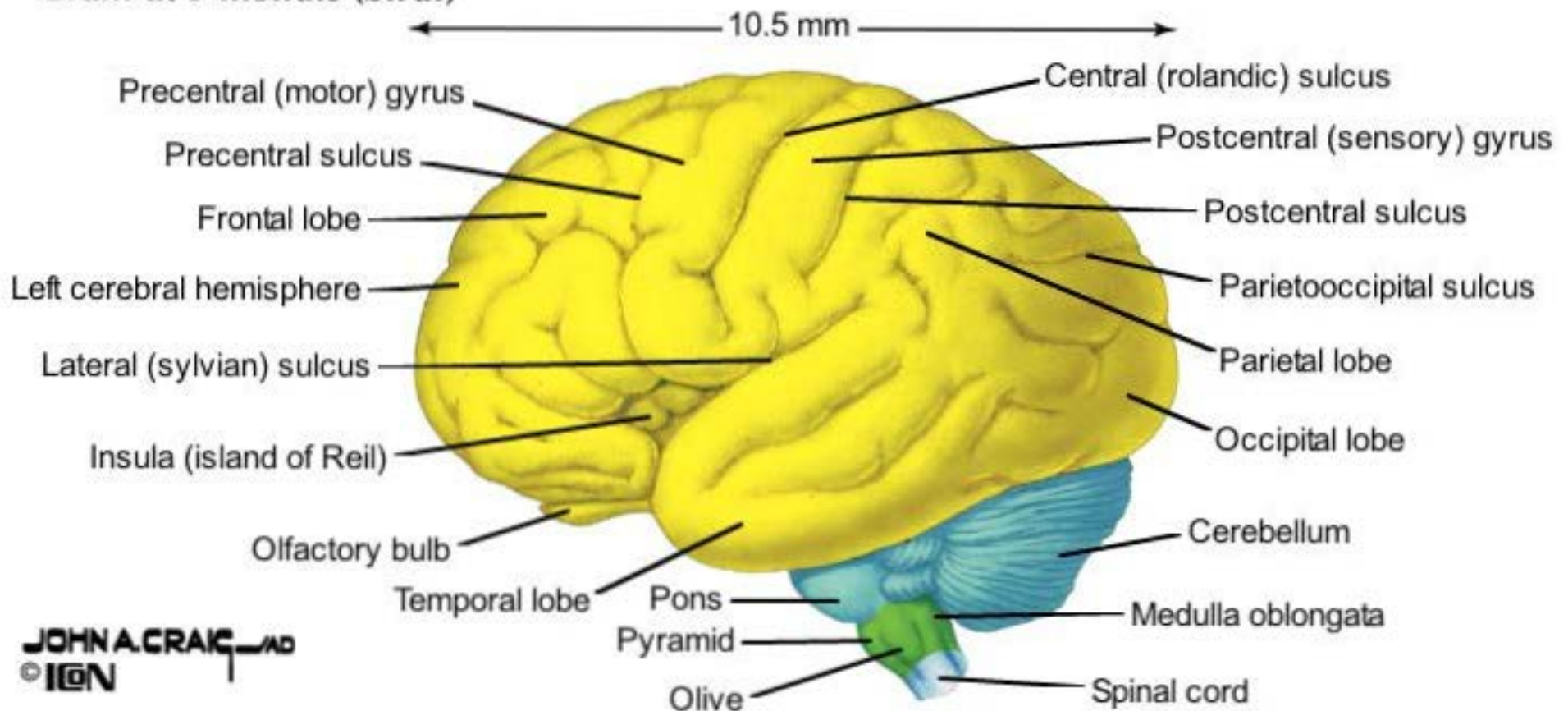


# Growth of the Cerebral Hemispheres

## Brain at 6 months



## Brain at 9 months (birth)

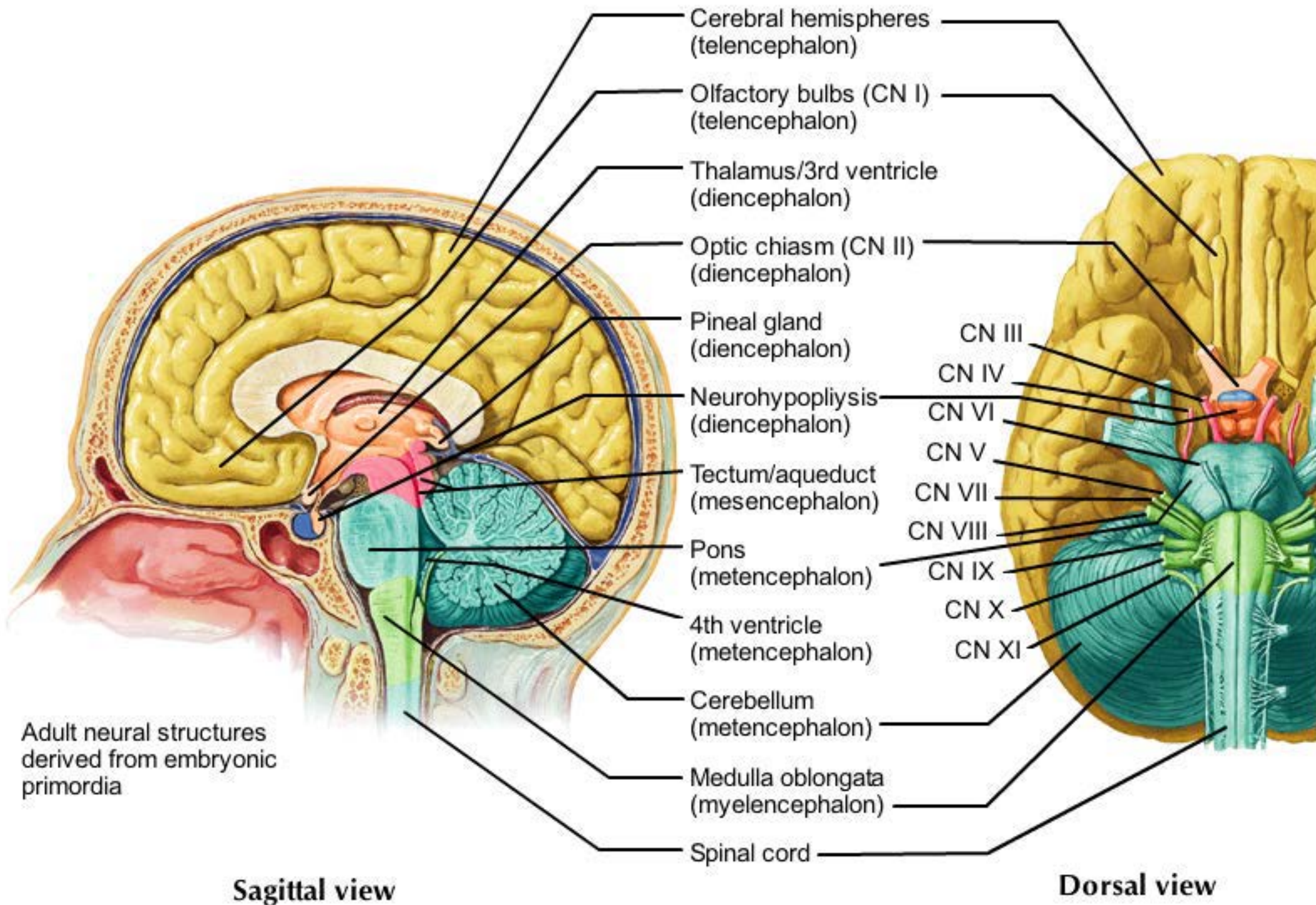




# Derivatives of the Forebrain, Midbrain, and Hindbrain

## Adult derivatives of brain primordia

JOHN A. CRAIG MD  
© IGCN

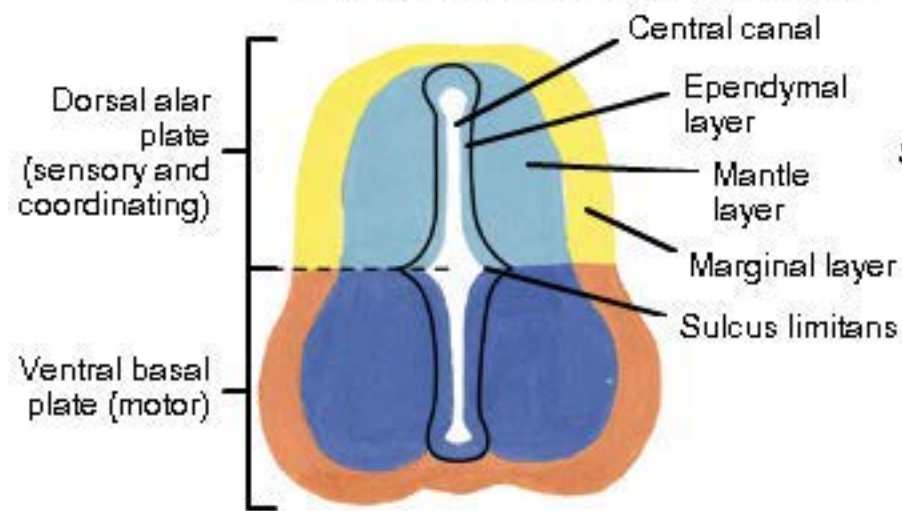




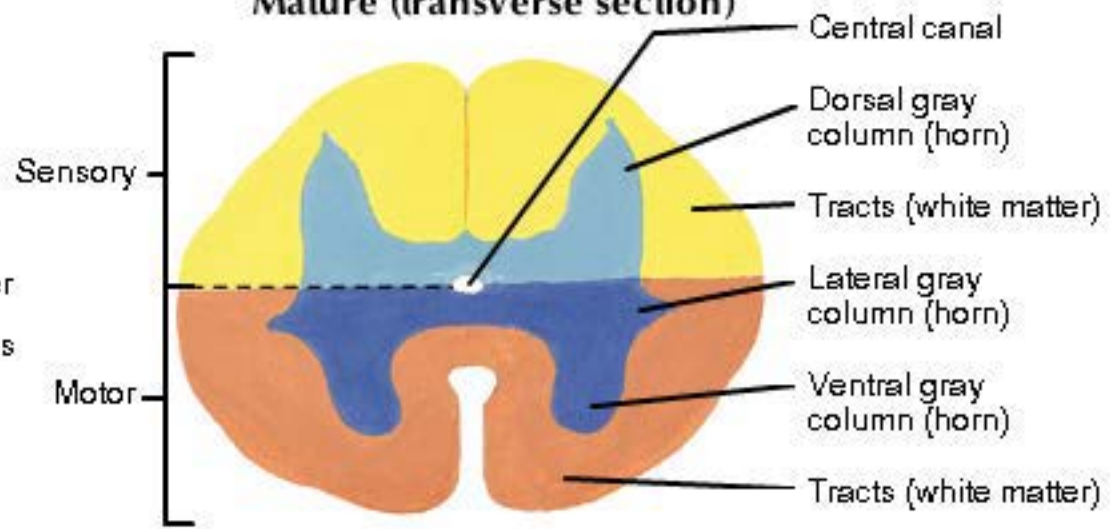
# Cross Sections of the Midbrain and Hindbrain

## Spinal cord

5 1/2 weeks (transverse section)

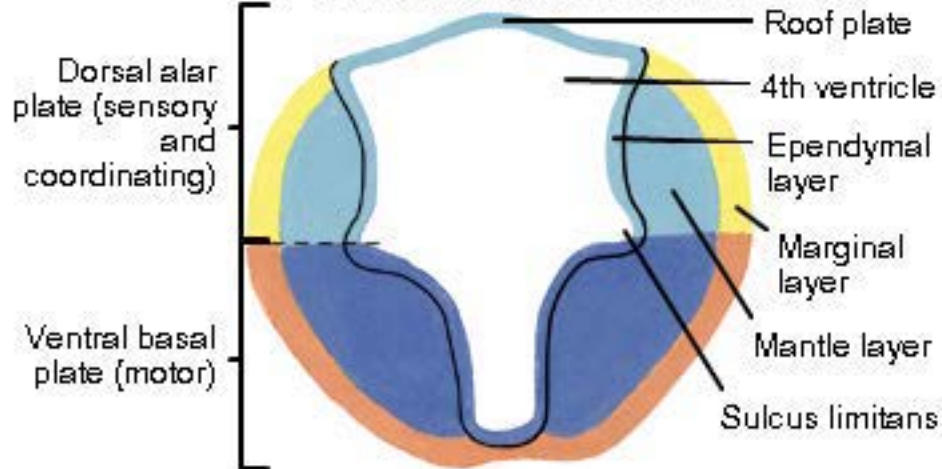


Mature (transverse section)

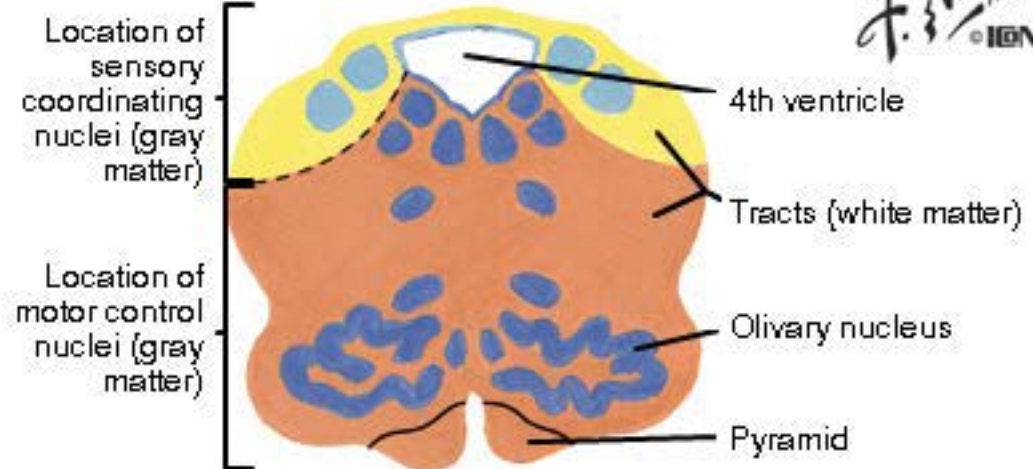


## Medulla oblongata

5 1/2 weeks (transverse section)



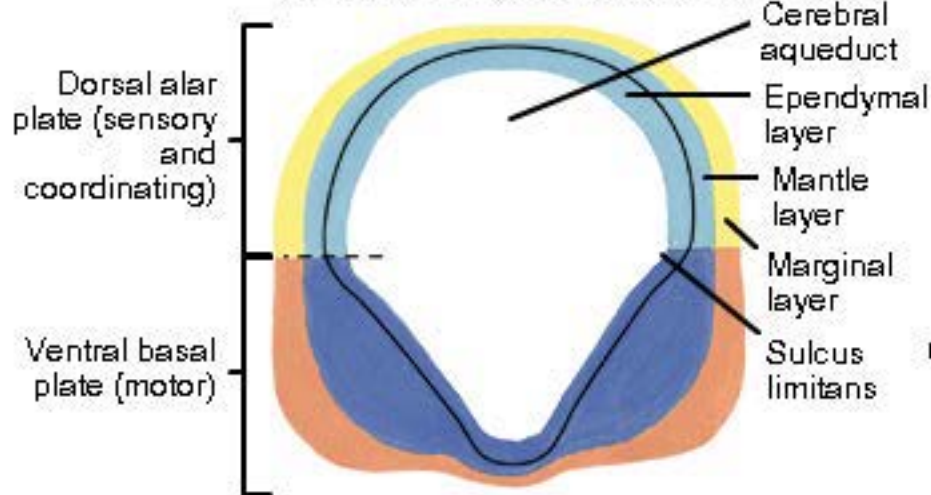
Mature (transverse section)



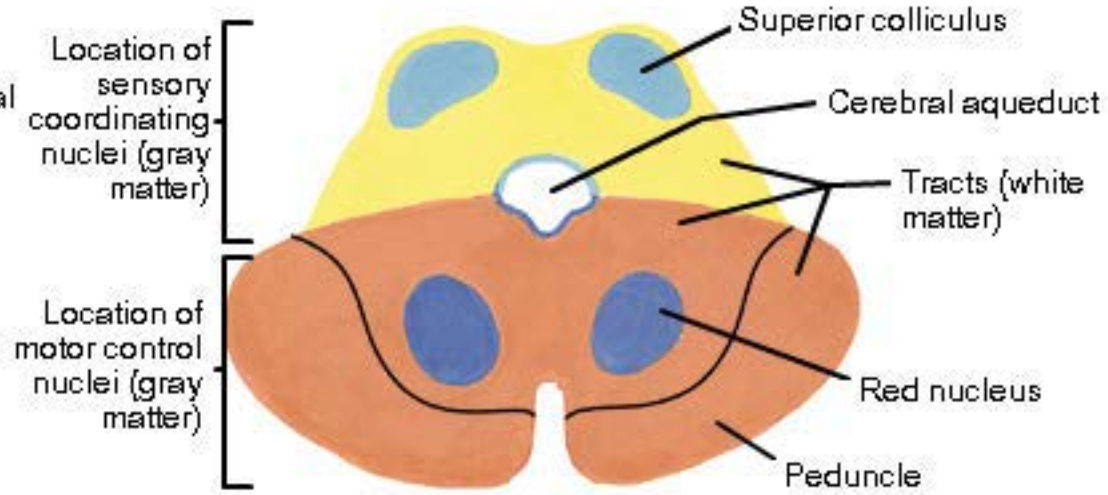
*F. Netter M.D.*  
© IGV

## Mesencephalon

5 1/2 weeks (transverse section)



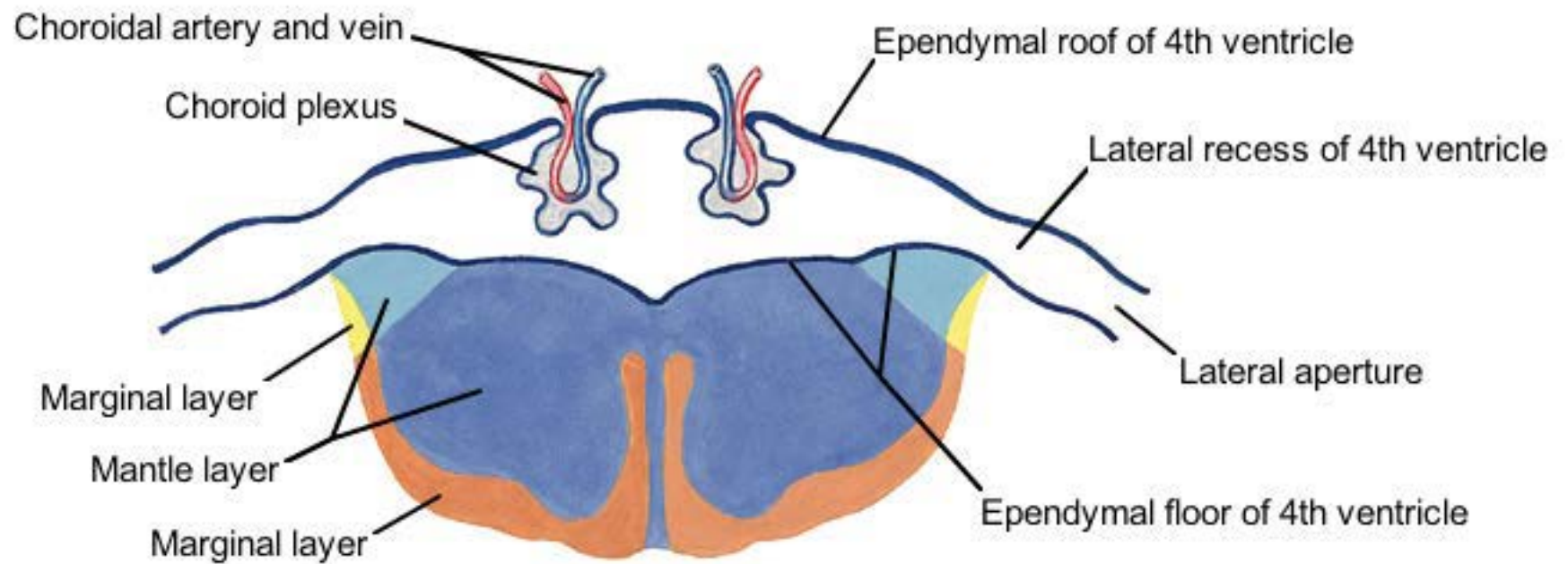
Mature (transverse section)



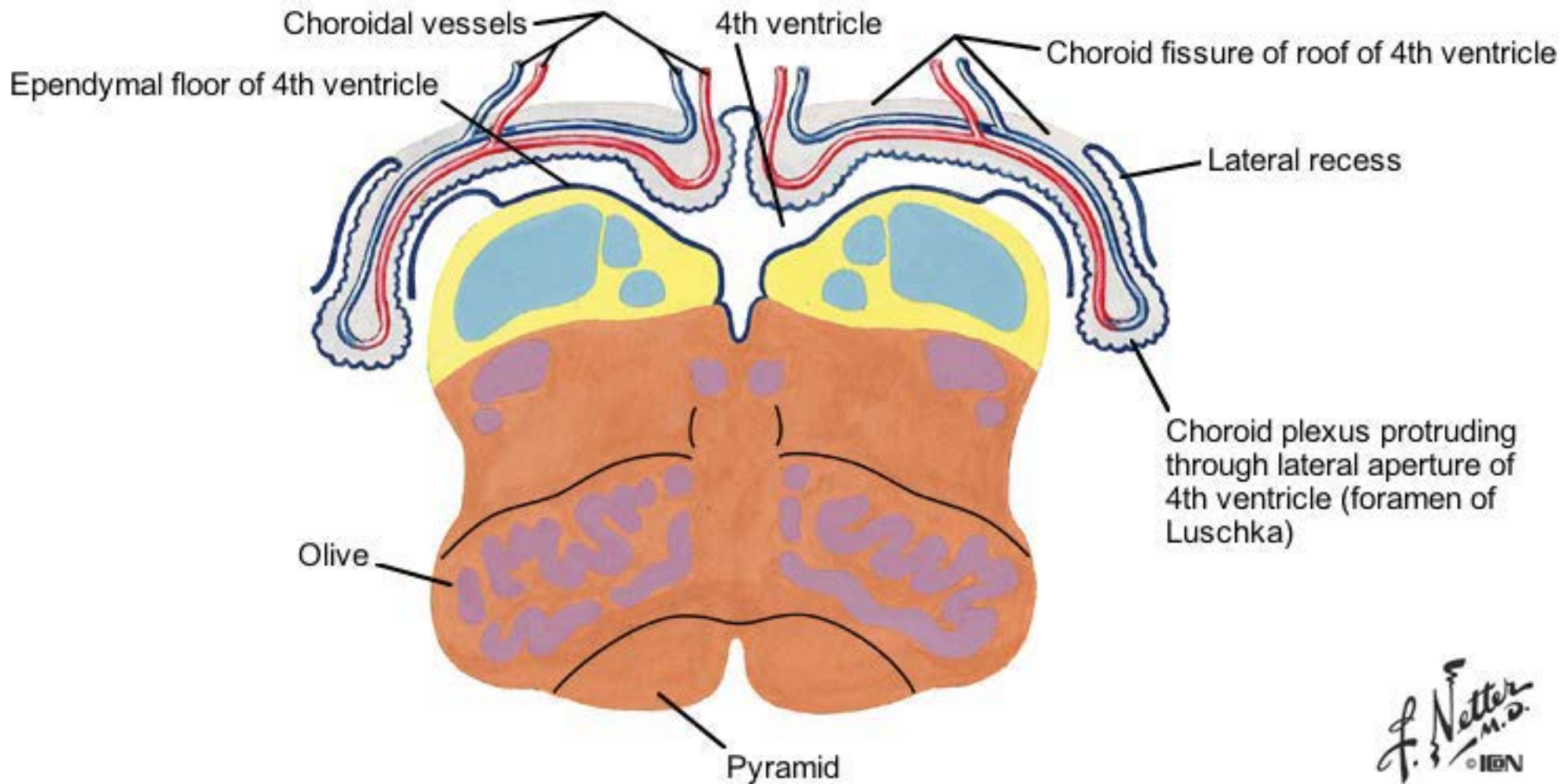


# Production of Cerebrospinal Fluid

## Medulla oblongata at 3 1/2 months (transverse section)

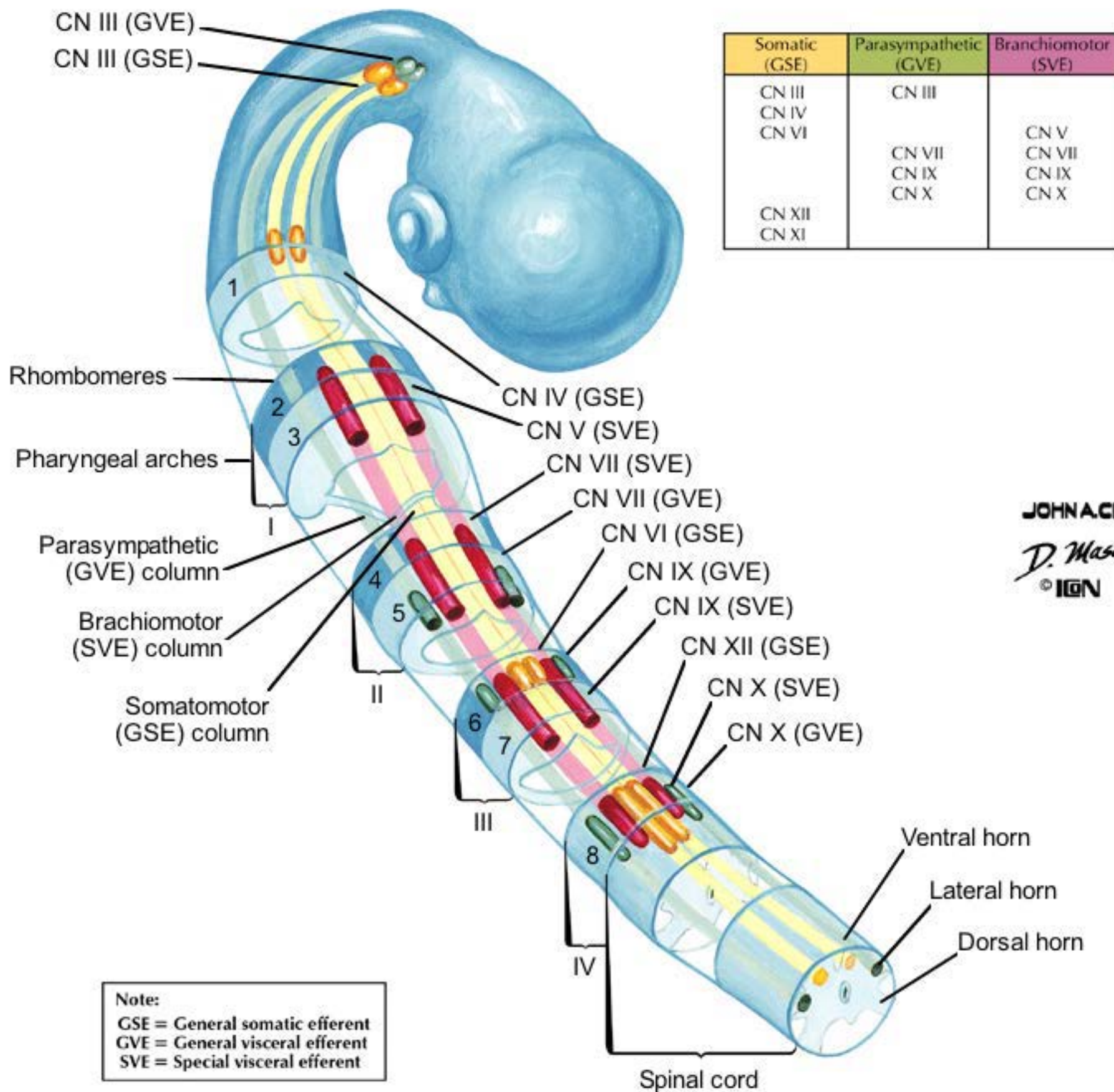


## Medulla oblongata, mature (transverse section)





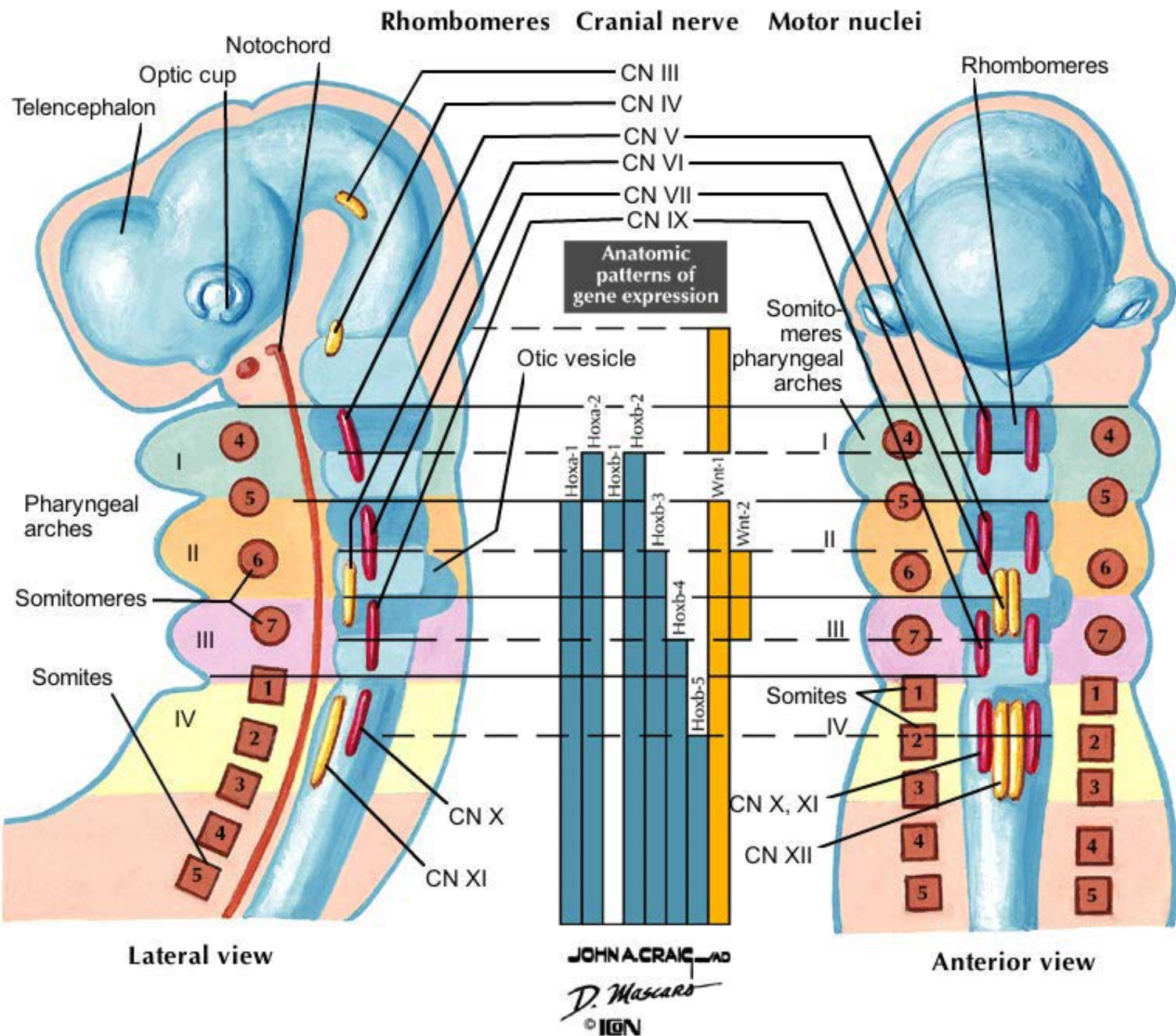
# Development of Motor Nuclei in the Brainstem



JOHN A. CRAIG, MD  
 D. Mascaro  
 © IGCN



# Segmentation of the Hindbrain

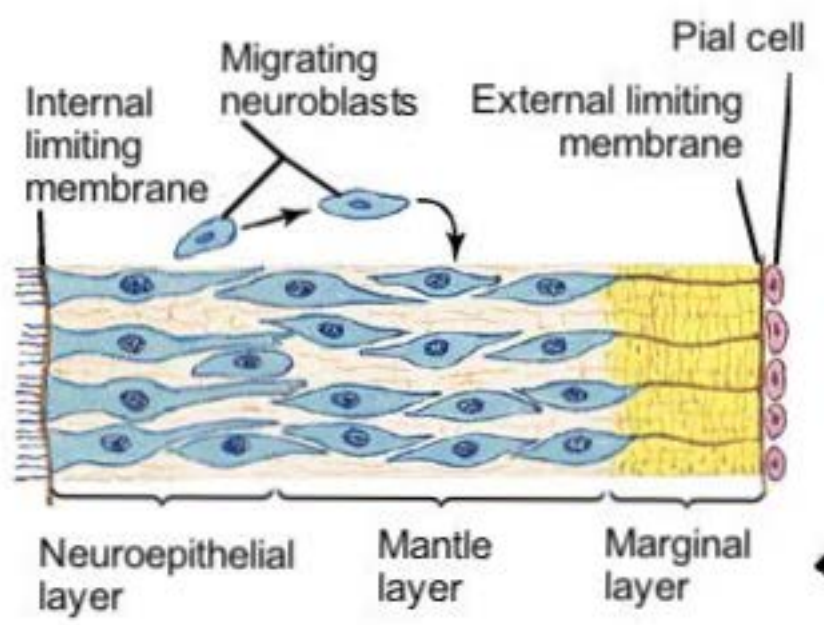




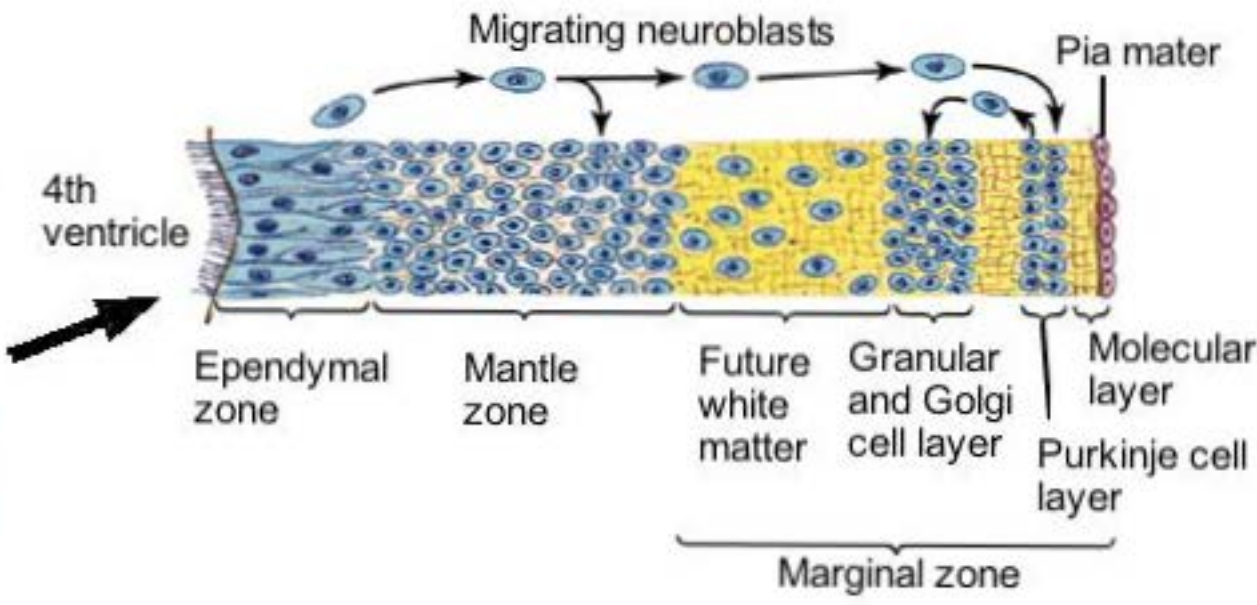
# Development of the Forebrain

## Differentiation of walls of neural tube

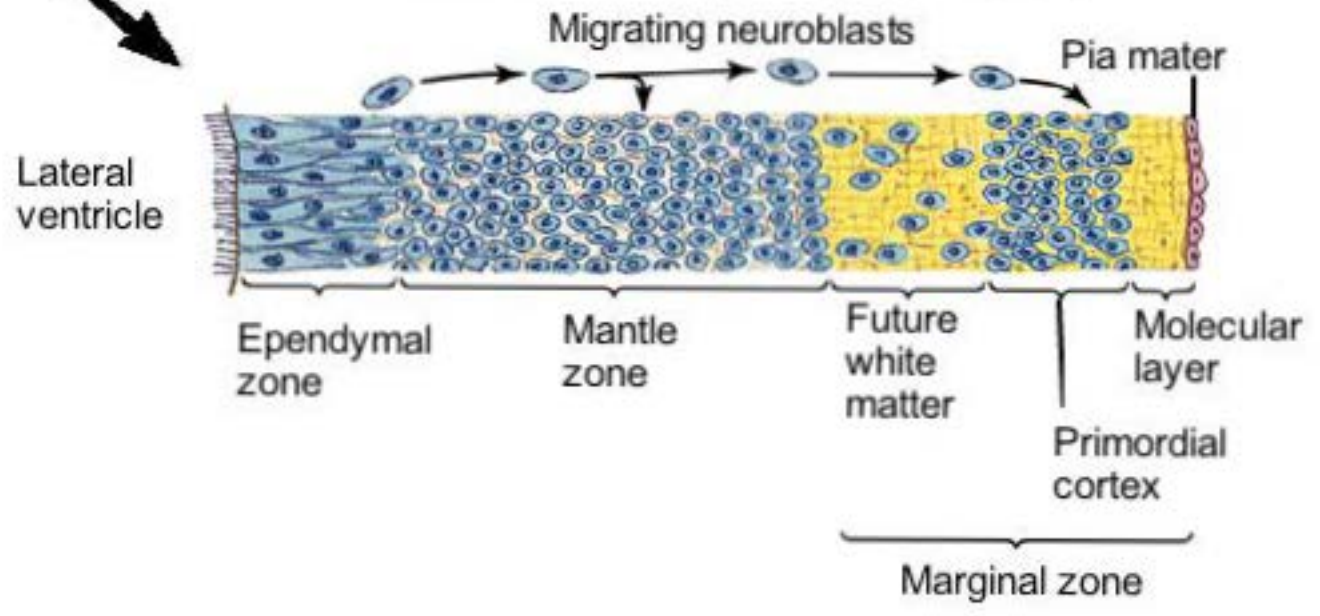
### Neural tube at 5 weeks



### Cerebellar hemisphere at 3 months

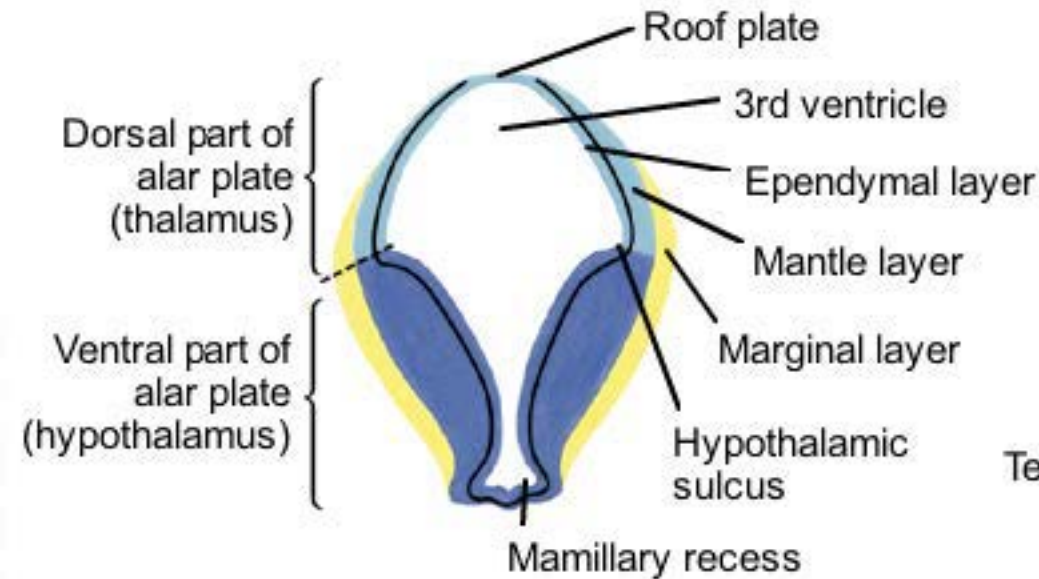


### Cerebral hemisphere at 3 months

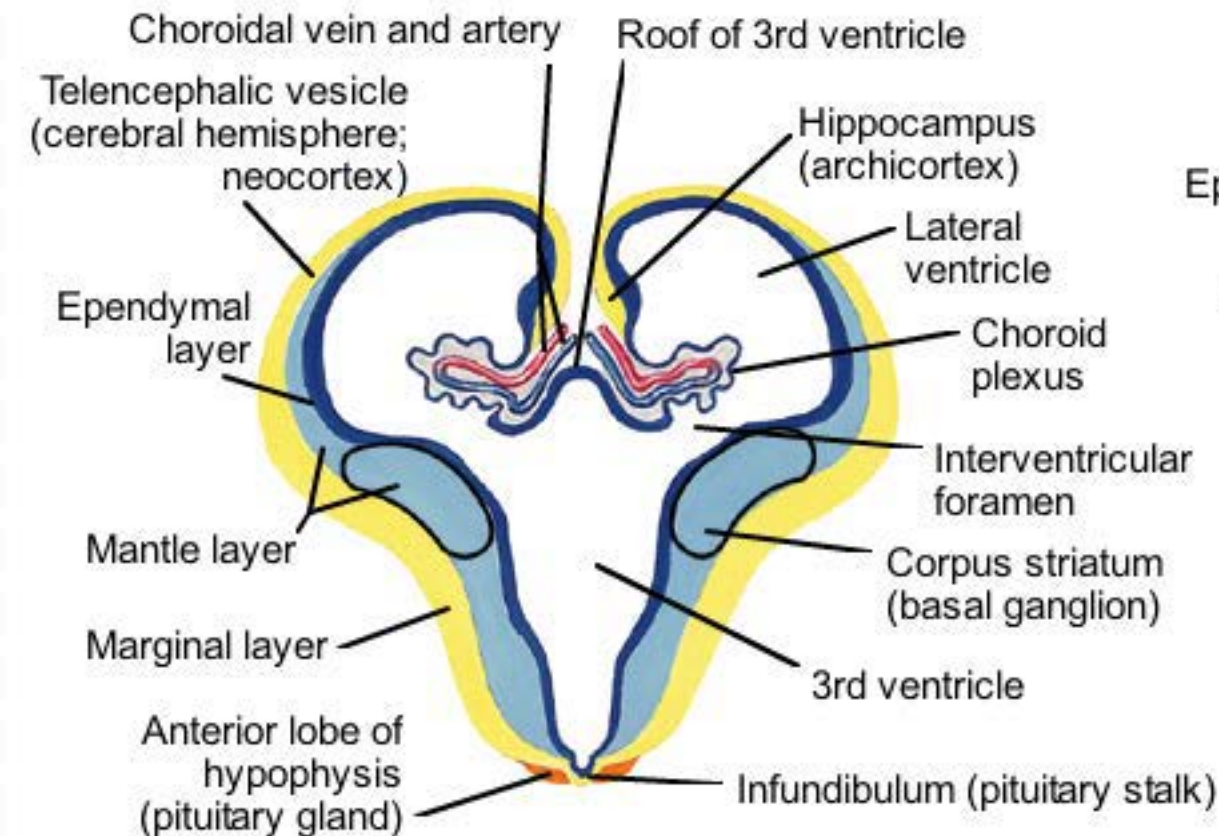


# Development of the Forebrain

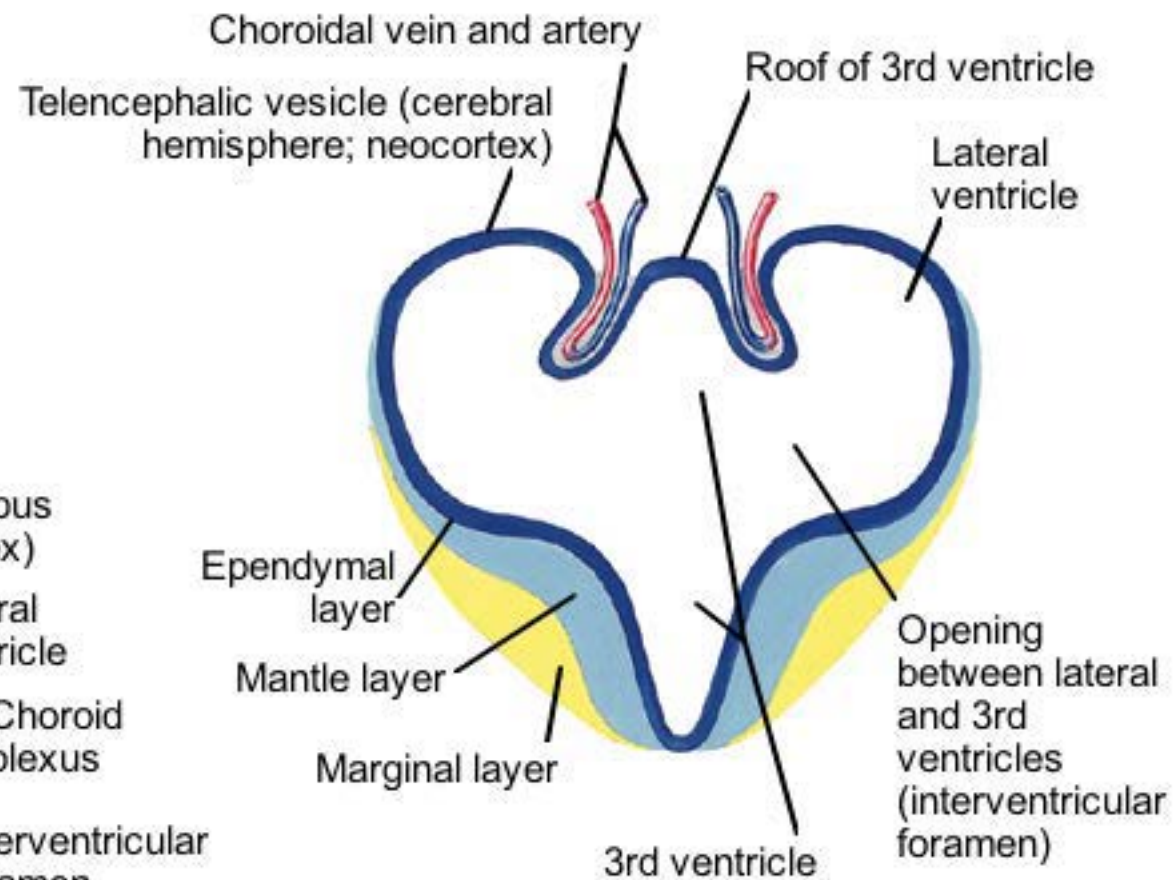
## Diencephalon 5 1/2 weeks (transverse section)



## Telencephalon at 7 1/2 weeks (transverse section)



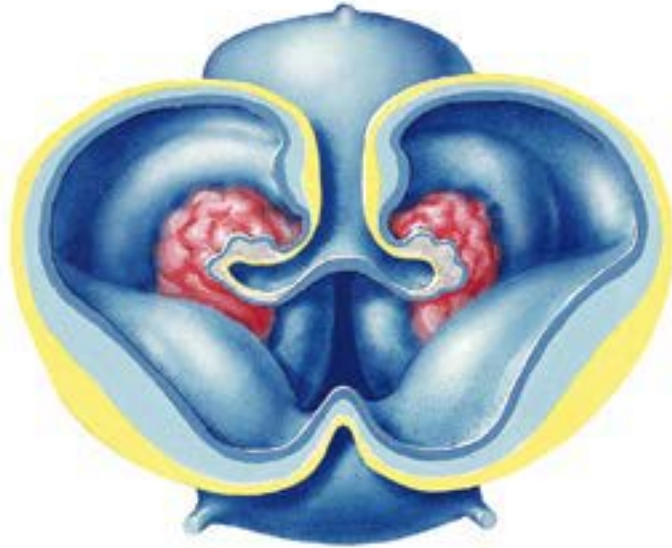
## Forebrain at 7 weeks (transverse section)



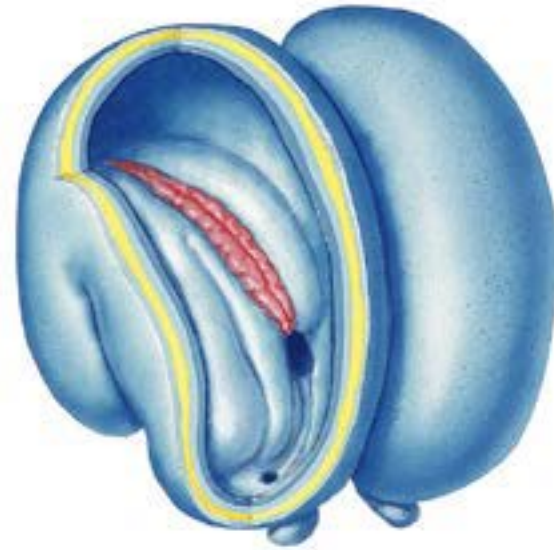


# Development of the Forebrain

Forebrain at 2 Months  
(coronal section; anterior view)



Telencephalon at 2 1/2 months  
(right anterior view)



Right cerebral hemisphere at 3 months  
(medial aspect)



Cerebral hemispheres at 3 months  
(coronal section)

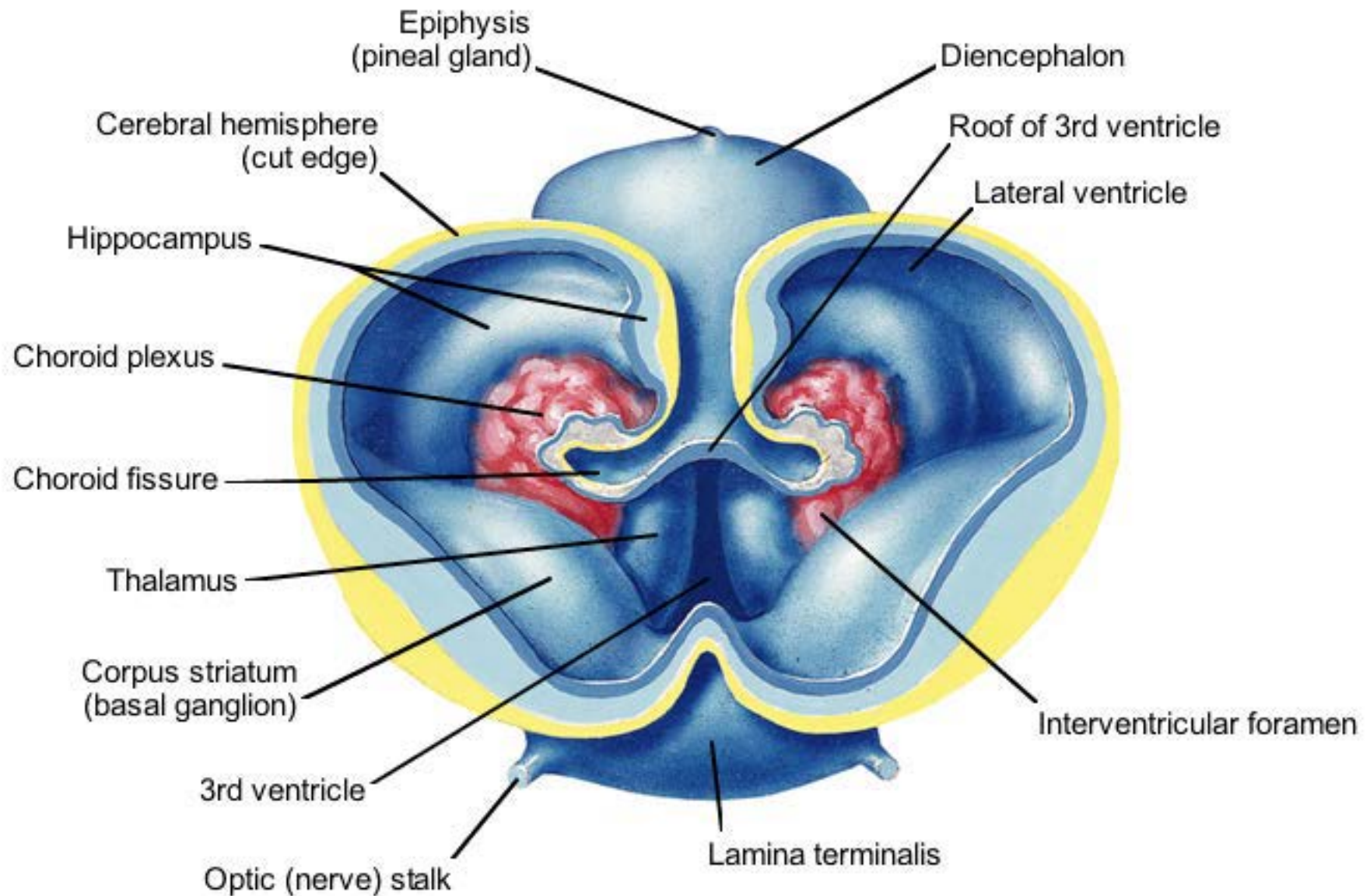


Diencephalon and telencephalon  
Mature (coronal section)



# Development of the Forebrain

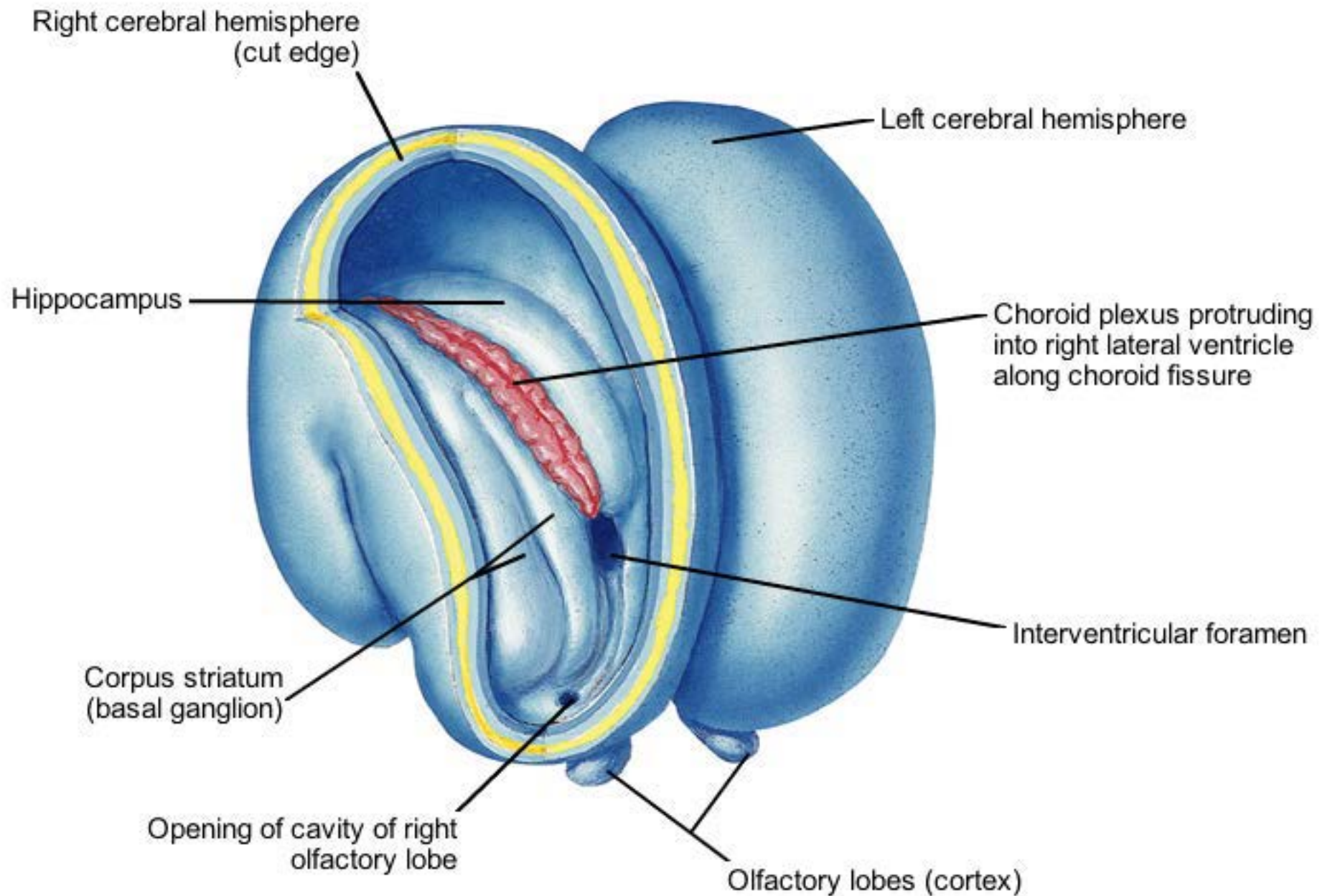
## Forebrain at 2 Months (coronal section; anterior view)





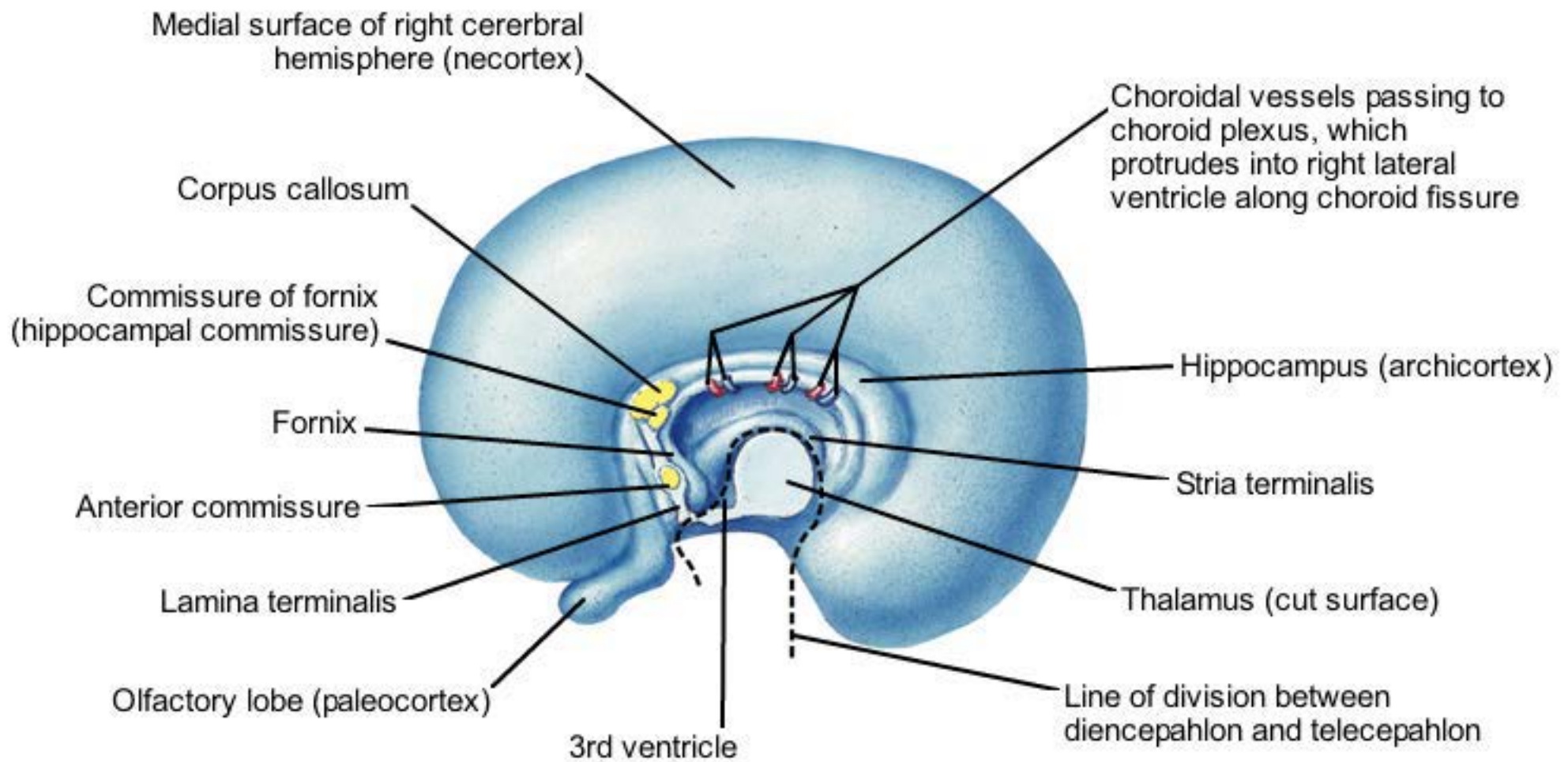
# Development of the Forebrain

## Telencephalon at 2 1/2 months (right anterior view)



# Development of the Forebrain

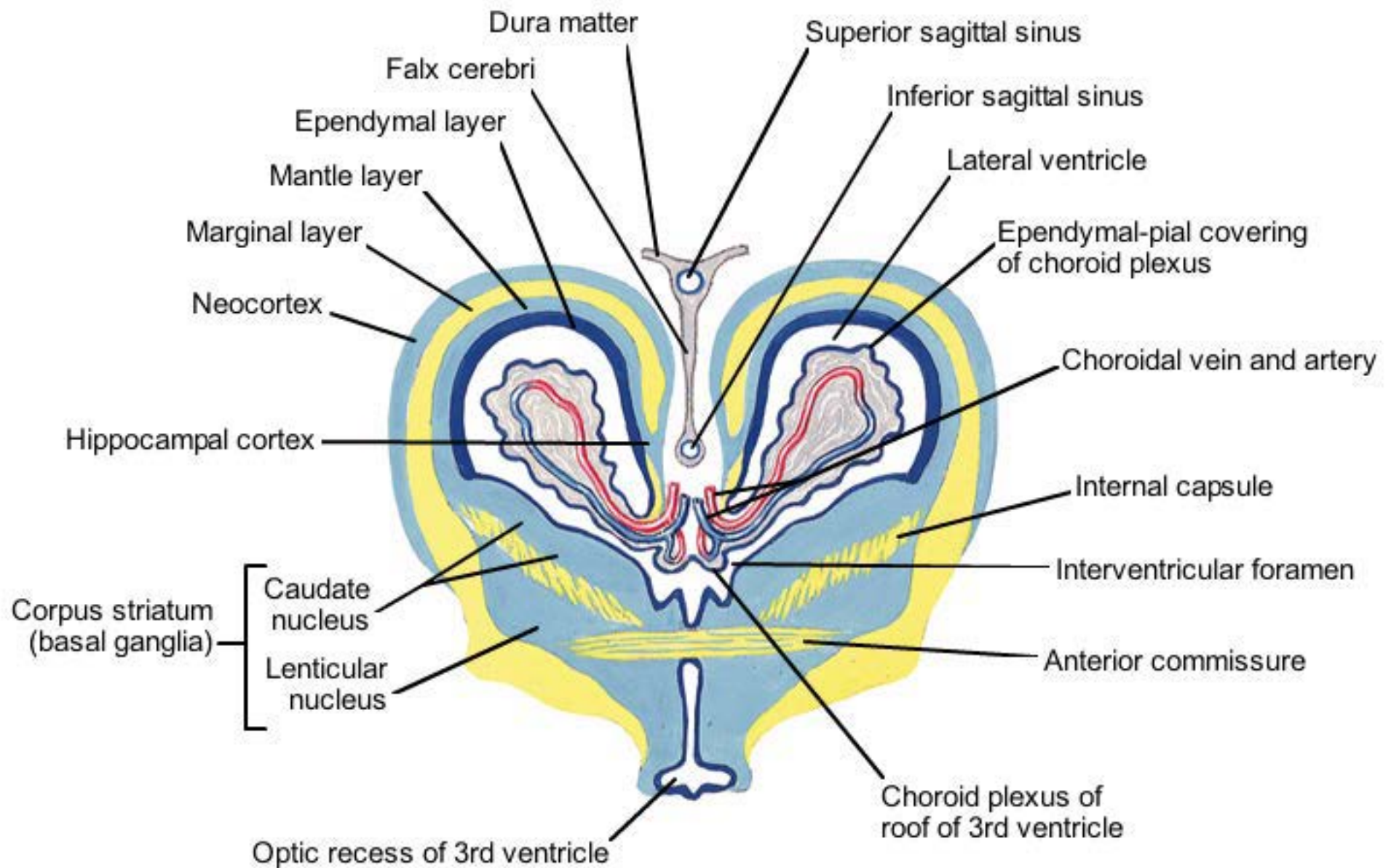
## Right cerebral hemisphere at 3 months (medial aspect)





# Development of the Forebrain

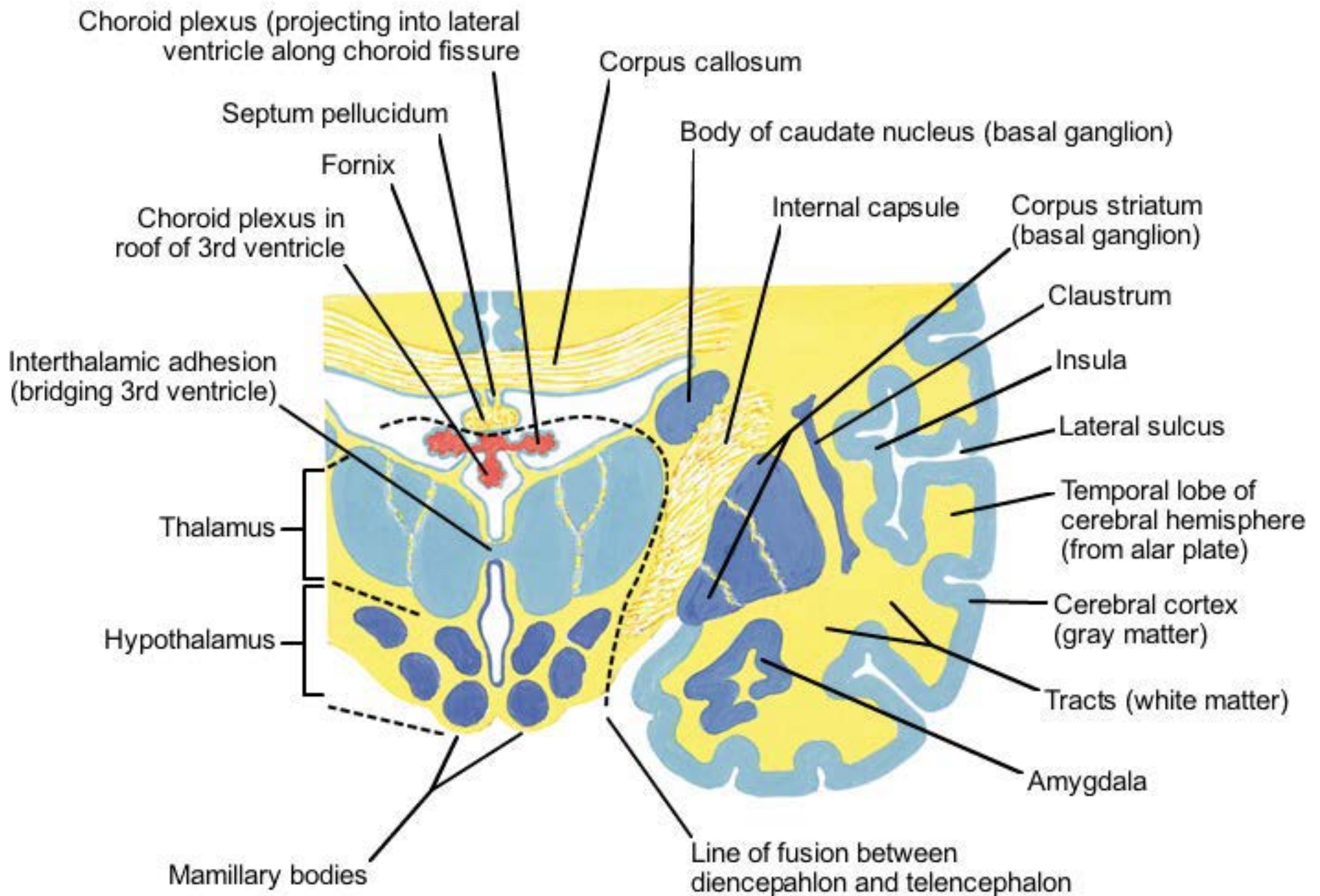
## Cerebral hemispheres at 3 months (coronal section)



# Development of the Forebrain

## Diencephalon and telencephalon

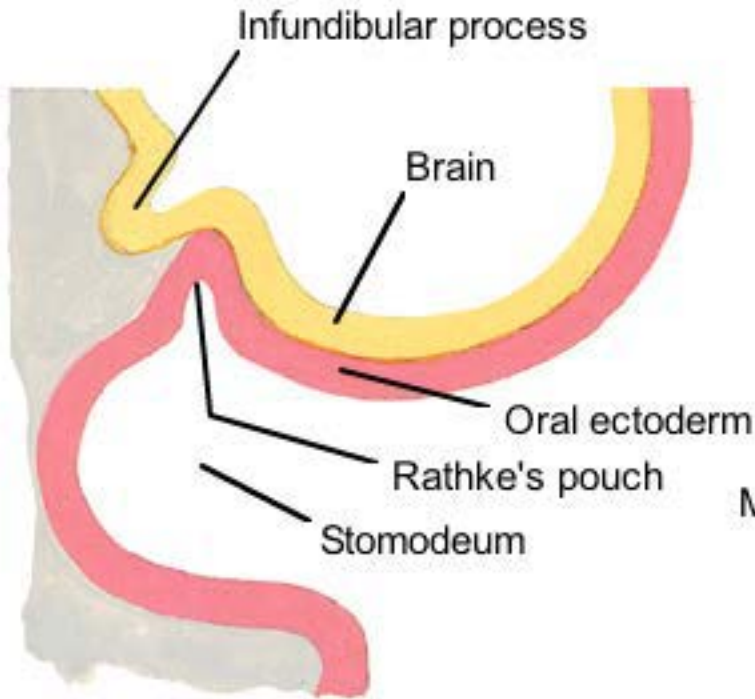
### Mature (coronal section)



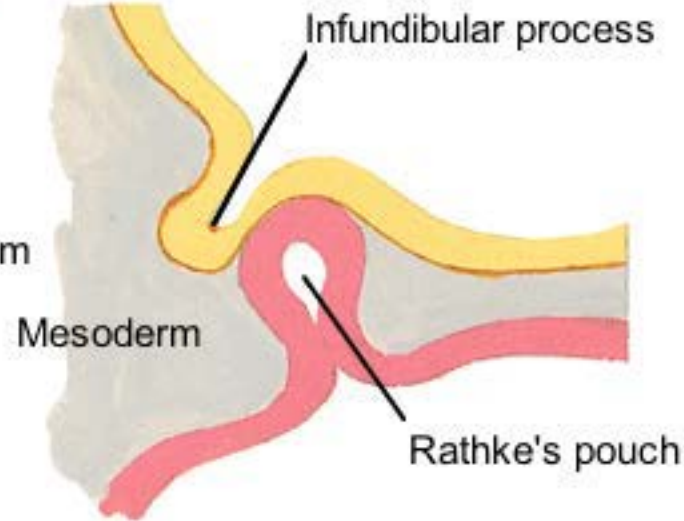


# Development of the Pituitary Gland

*F. Netter M.D.*  
© I&N



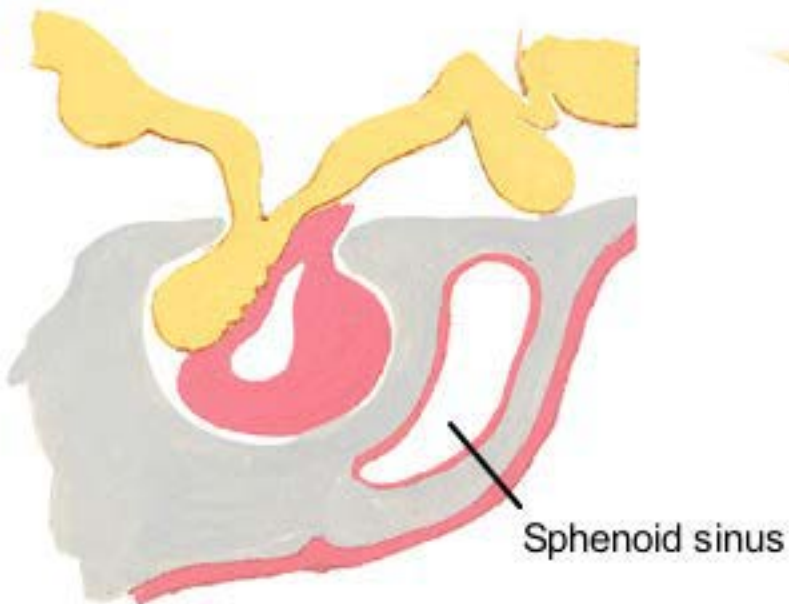
1. Beginning formation of Rathke's pouch and infundibular process



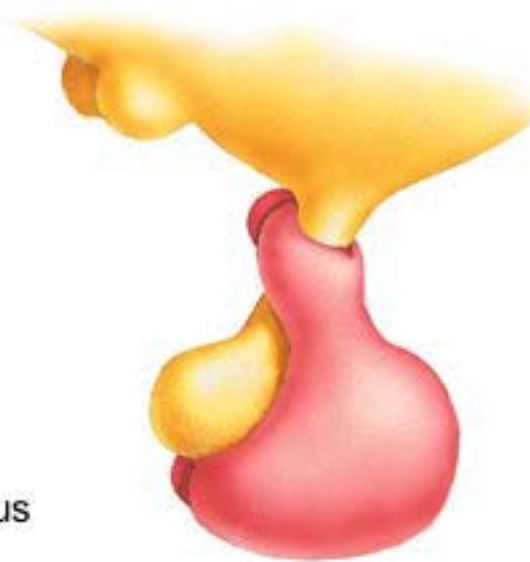
2. Neck of Rathke's pouch constricted by growth of mesoderm



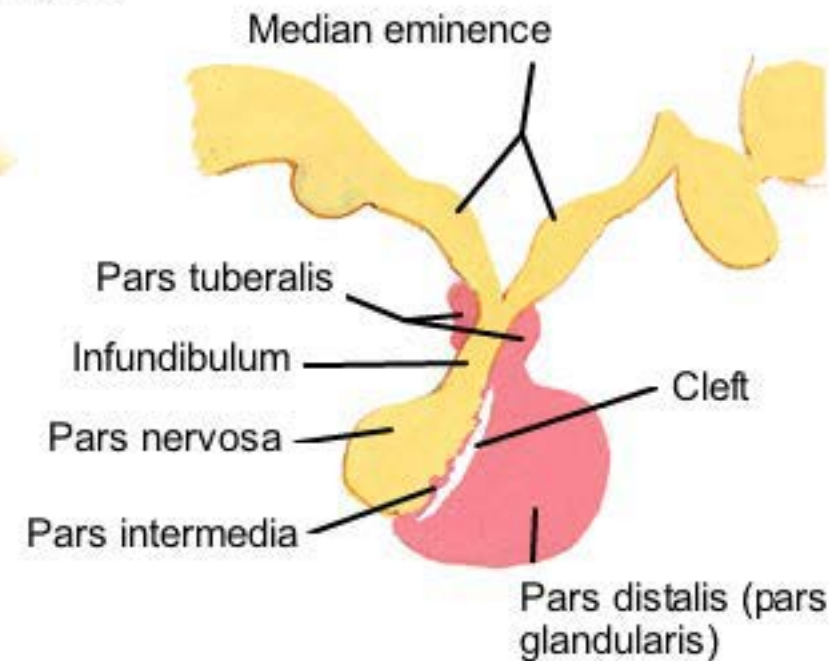
3. Rathke's pouch "pinched off"



4. "Pinched off" segment conforms to neural process, forming pars distalis, pars intermedia and pars tuberalis



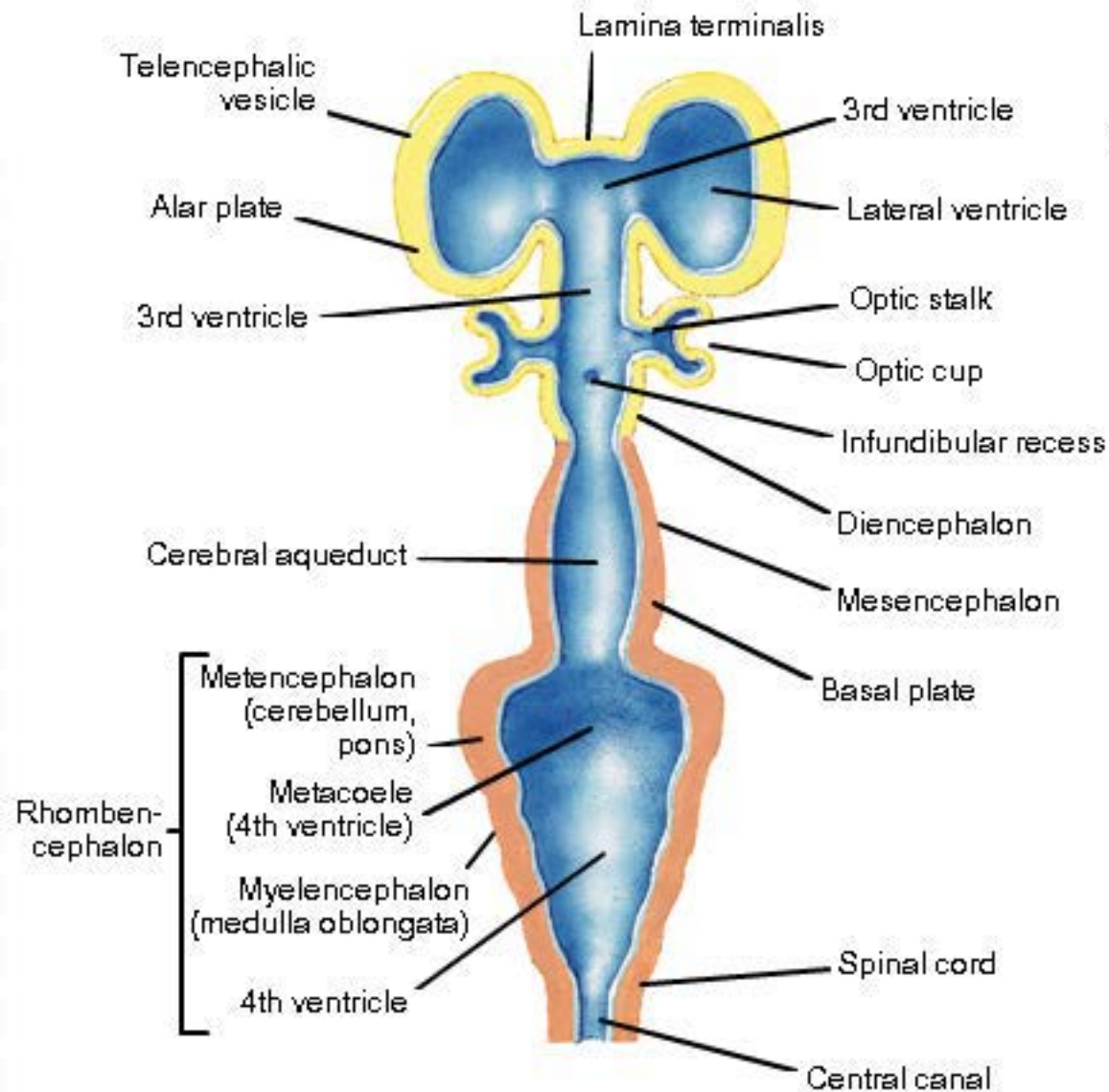
5. Pars tuberalis encircles infundibular stalk (lateral surface view)



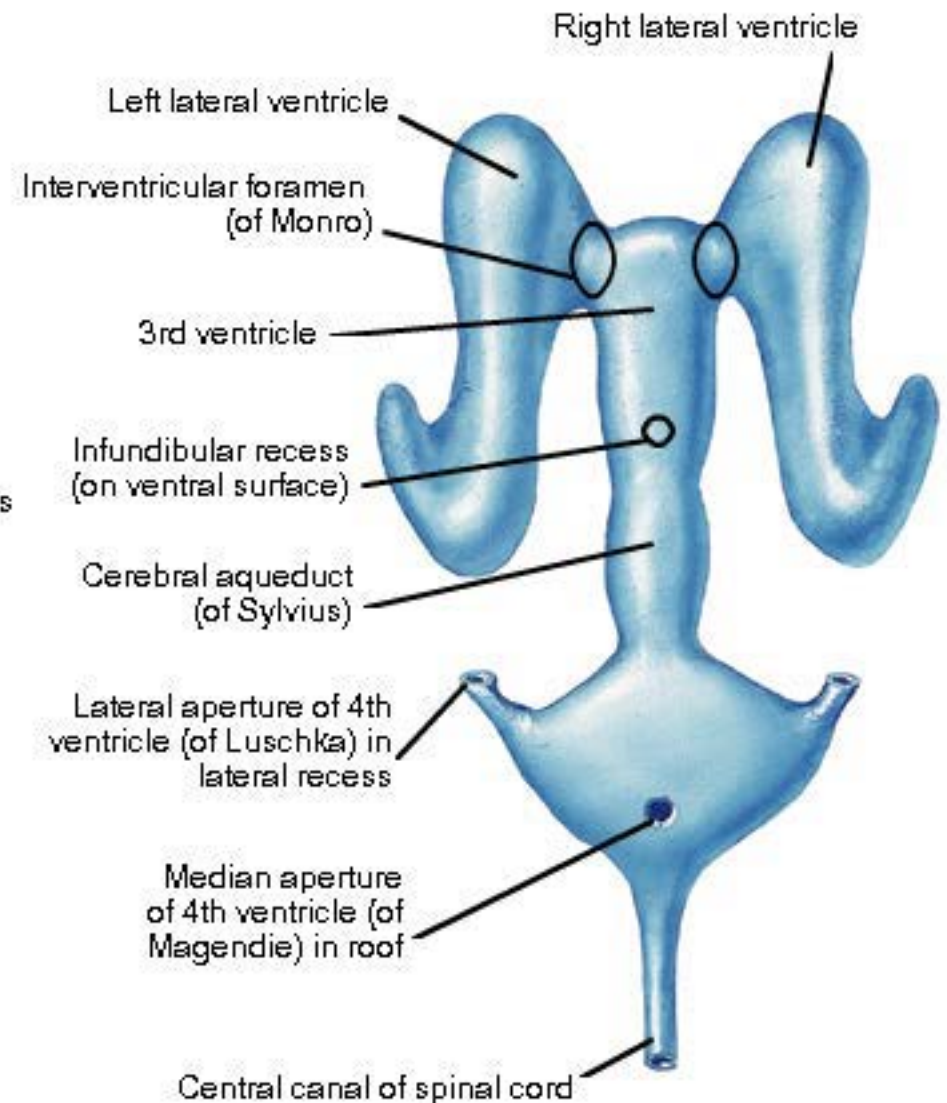
6. Mature form

# Development of the Ventricles

Frontal section (ventral to sulcus limitans) at 36 days



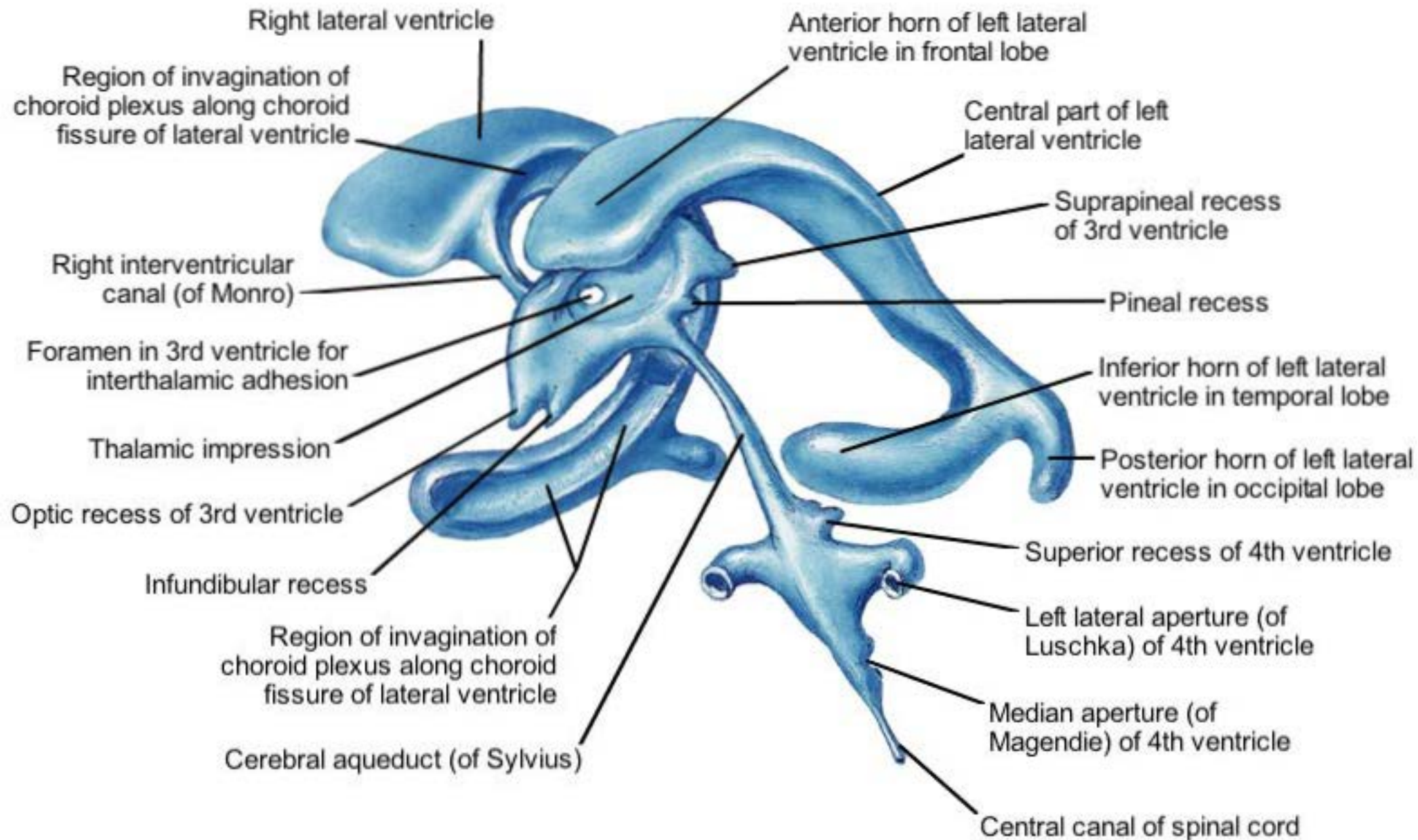
Ependymal lining of cavities of brain at 3 months





# Development of the Ventricles

## Ependymal lining of cavities of brain at 9 months (birth)





# Congenital Ventricular Defects

## Hydrocephalus

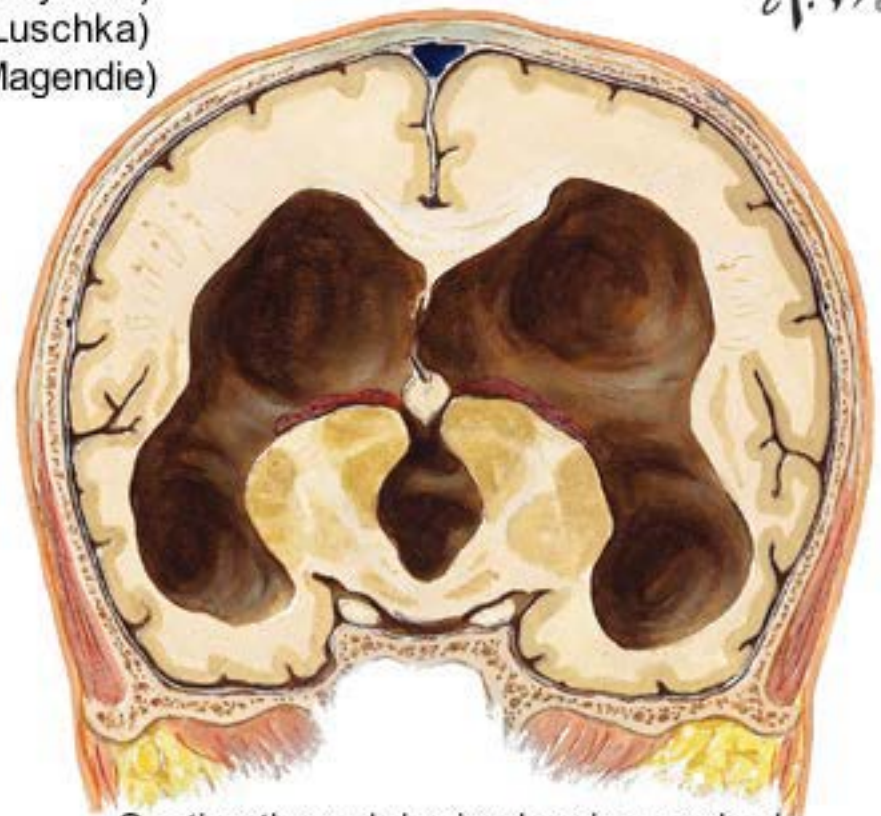
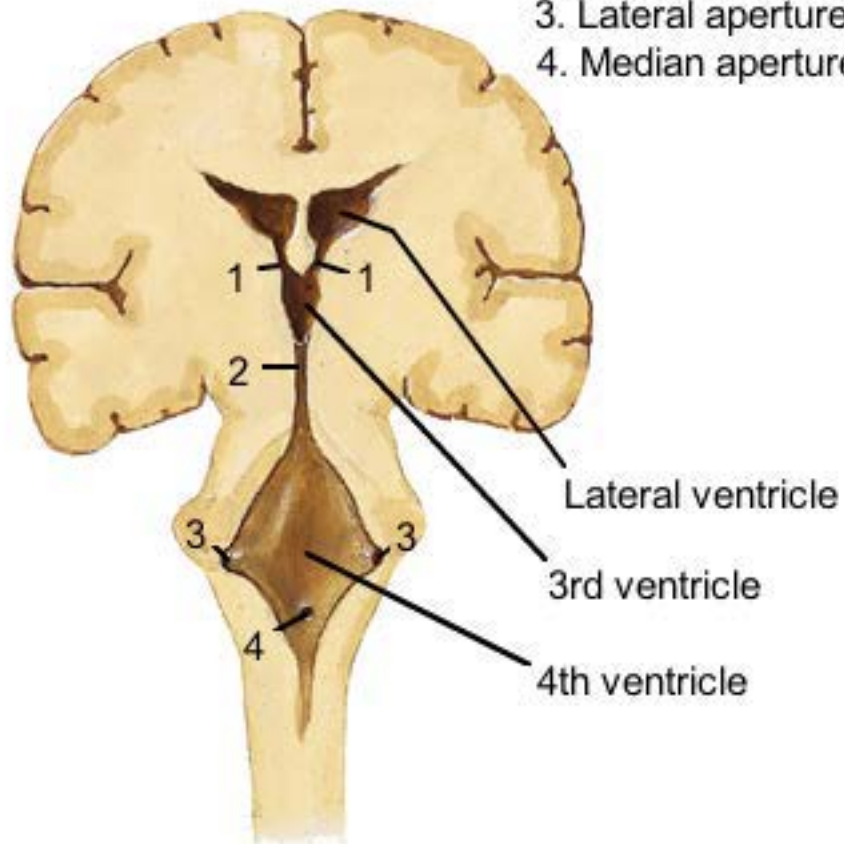


Clinical appearance in advanced hydrocephalus

### Potential lesion sites in obstructive hydrocephalus

1. Interventricular foramina (of Monro)
2. Cerebral aqueduct (of Sylvius)
3. Lateral apertures (of Luschka)
4. Median aperture (of Magendie)

*f. Netter*  
M.D.  
© IGV



Section through brain showing marked dilation of lateral and 3rd ventricles



# Adult Derivatives of the Forebrain, MidBrain, and Hindbrain

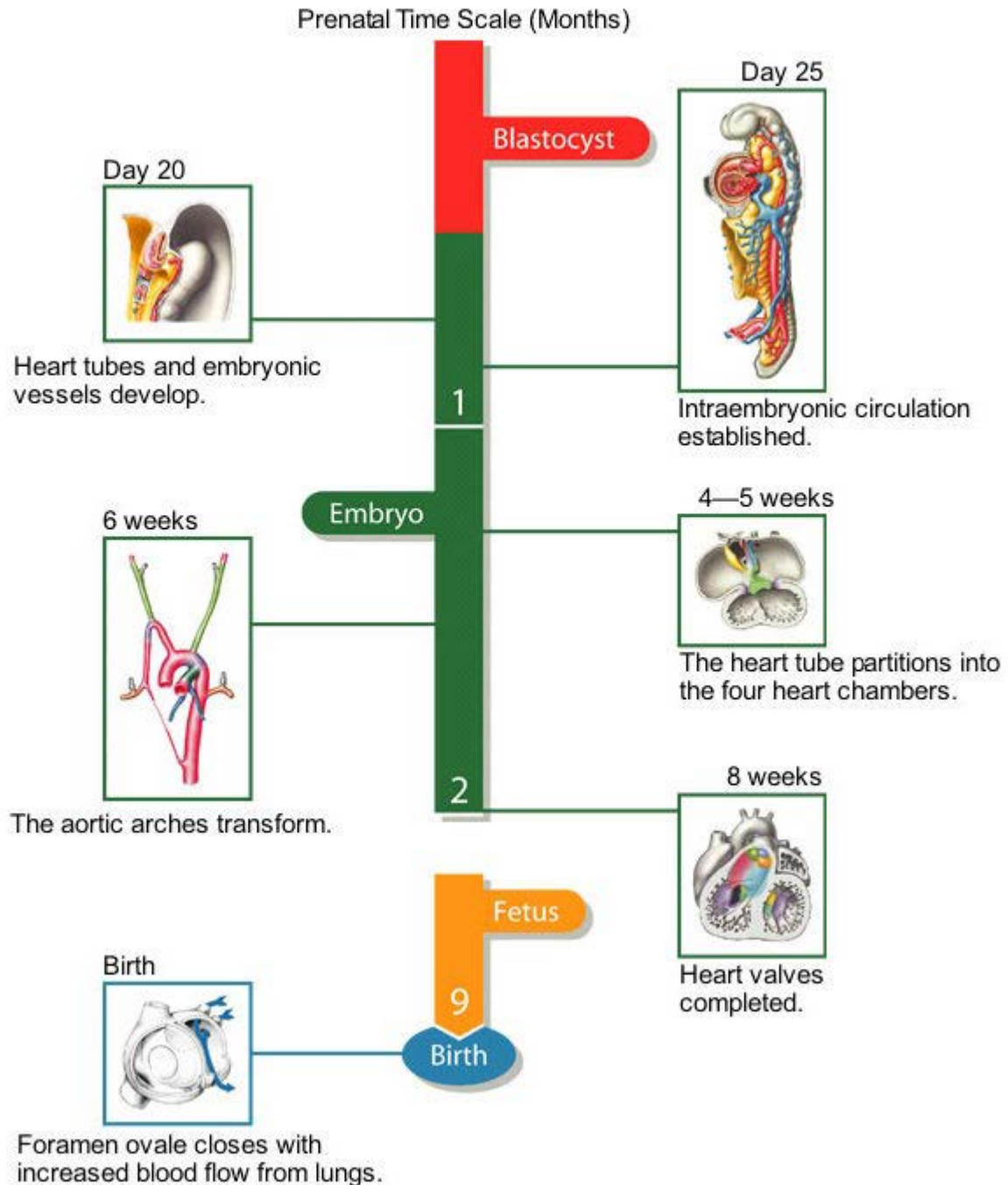
Forebrain	Telencephalon	Cerebral hemispheres (neocortex) Olfactory cortex (paleocortex) Hippocampus (archicortex) Basal ganglia/corpus striatum Lateral and 3rd ventricles	Nerves: Olfactory (I)
	Diencephalon	Optic cup/nerves Thalamus Hypothalamus Mammillary bodies Part of 3rd ventricle	Optic (II)
Midbrain	Mesencephalon	Tectum (superior, inferior colliculi) Cerebral aqueduct Red nucleus Substantia nigra Crus cerebelli	Oculomotor (III) Trochlear (IV)
Hindbrain	Metencephalon	Pons Cerebellum	Trigeminal (V) Abducens(VI) Facial (VII) Acoustic (VIII) Glossopharyngeal (IX) Vagus (X) Hypoglossal (XI)
	Myelencephalon	Medulla oblongata	

# Pituitary Hormones

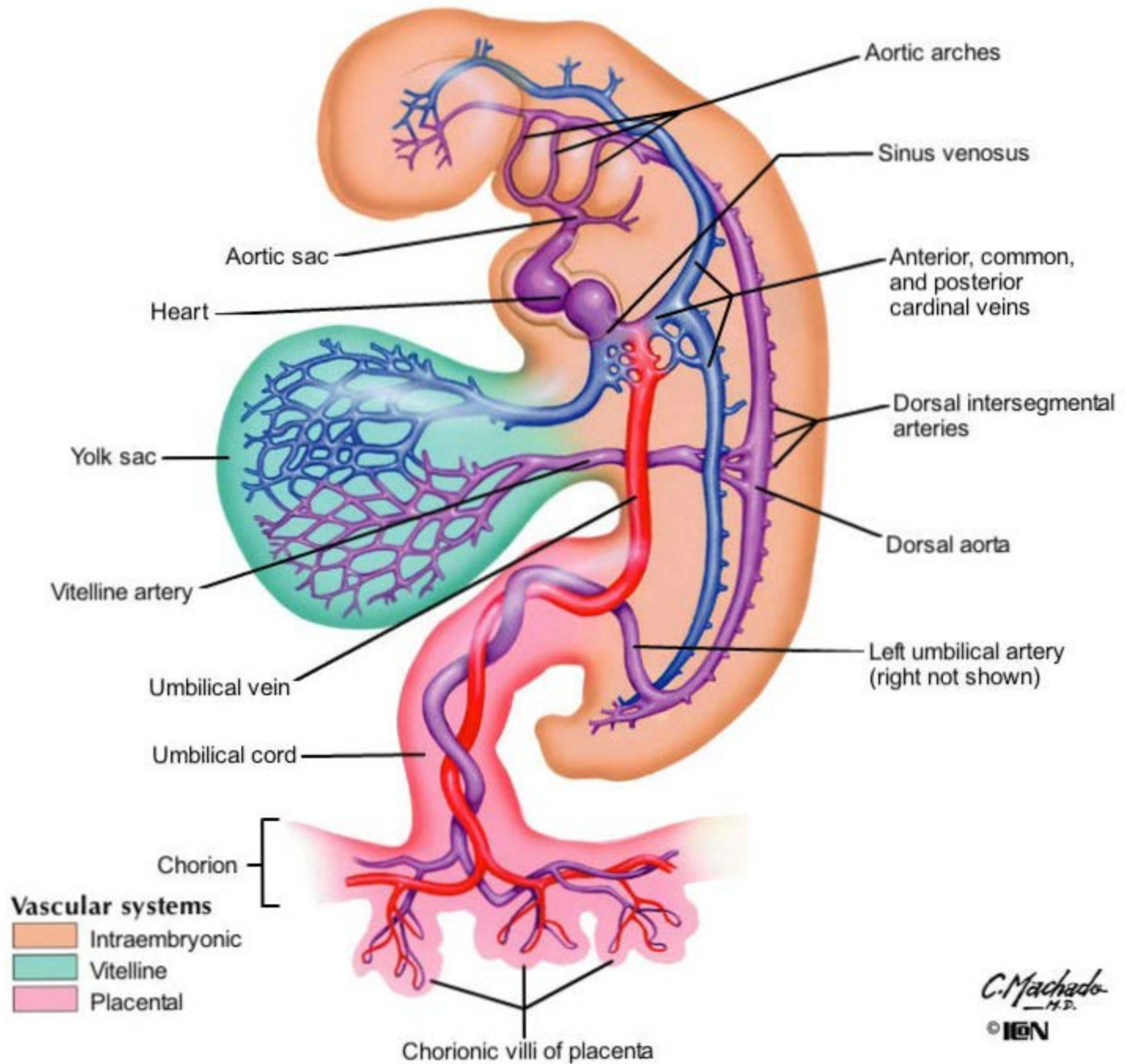
From the Anterior Lobe (Pars Distalis)		From the Posterior Lobe (Pars Nervosa)
Follicle-stimulating hormone (FSH)	Thyroid-stimulating hormone (TSH)	Vasopressin
Luteinizing hormone (LH)	Adrenocorticotrophic hormone (ACTH)	Oxytocin
Prolactin	Growth hormone (GH)	



# THE CARDIOVASCULAR SYSTEM TIMELINE

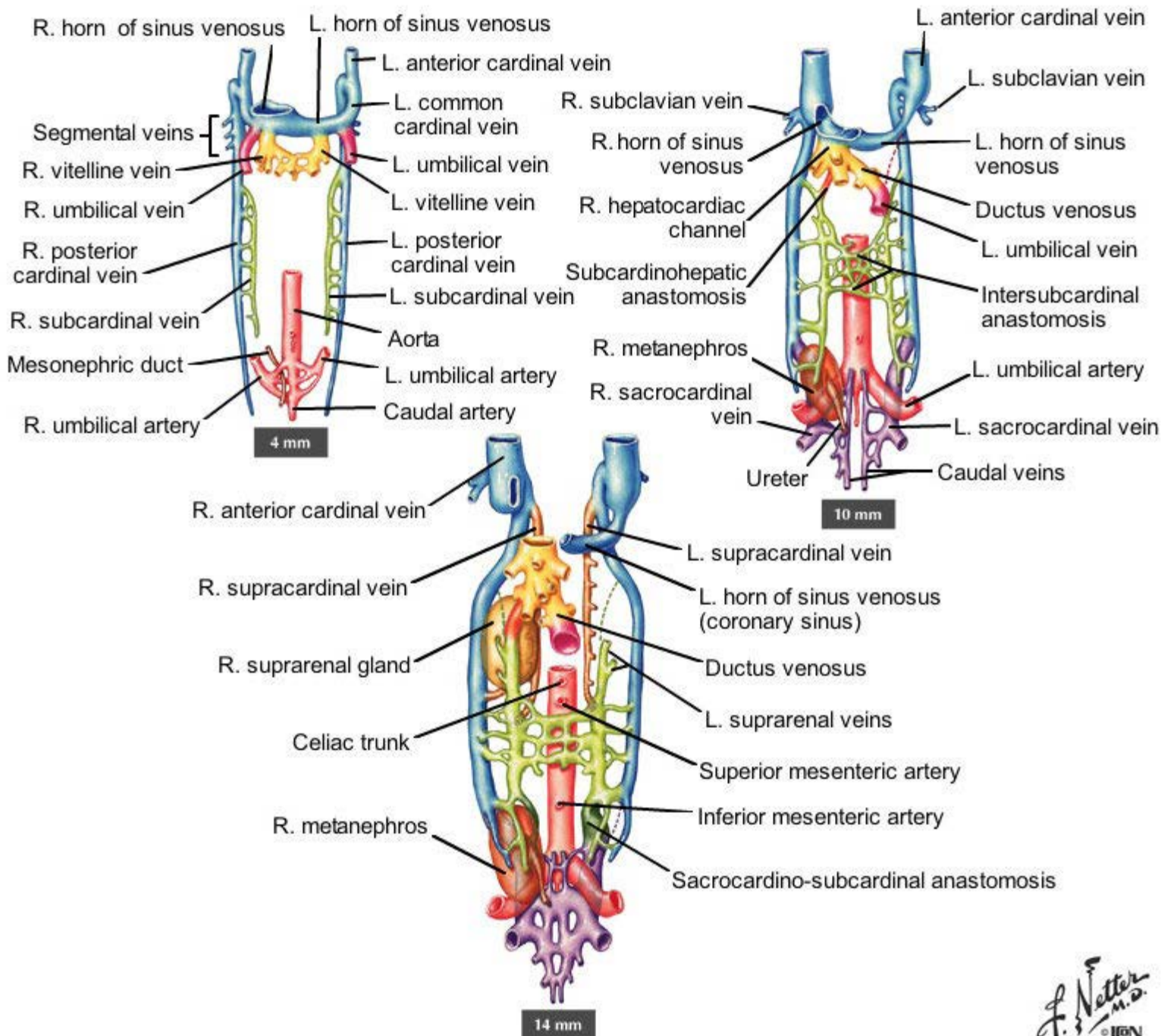


# Early Vascular Systems

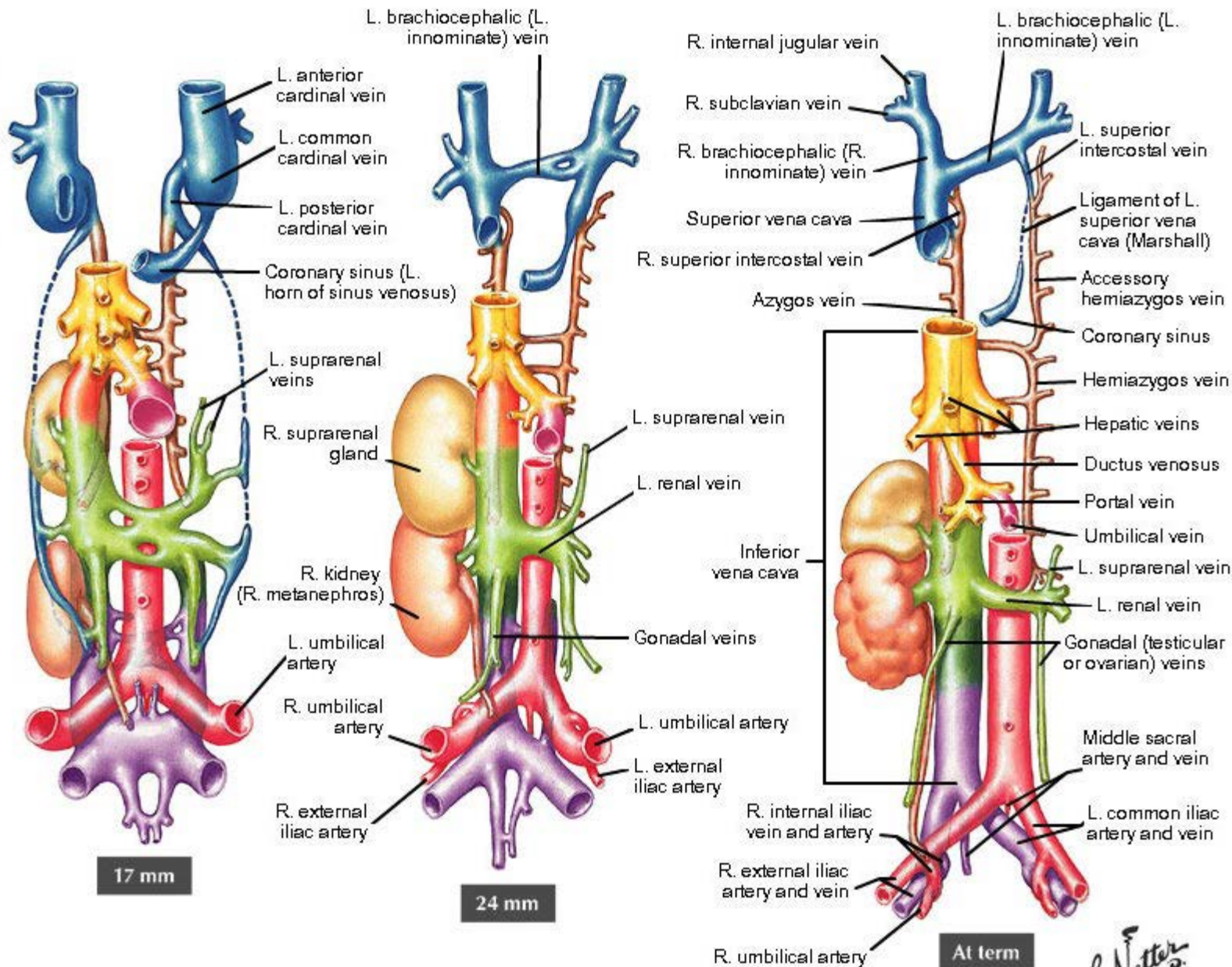




# Vein Development

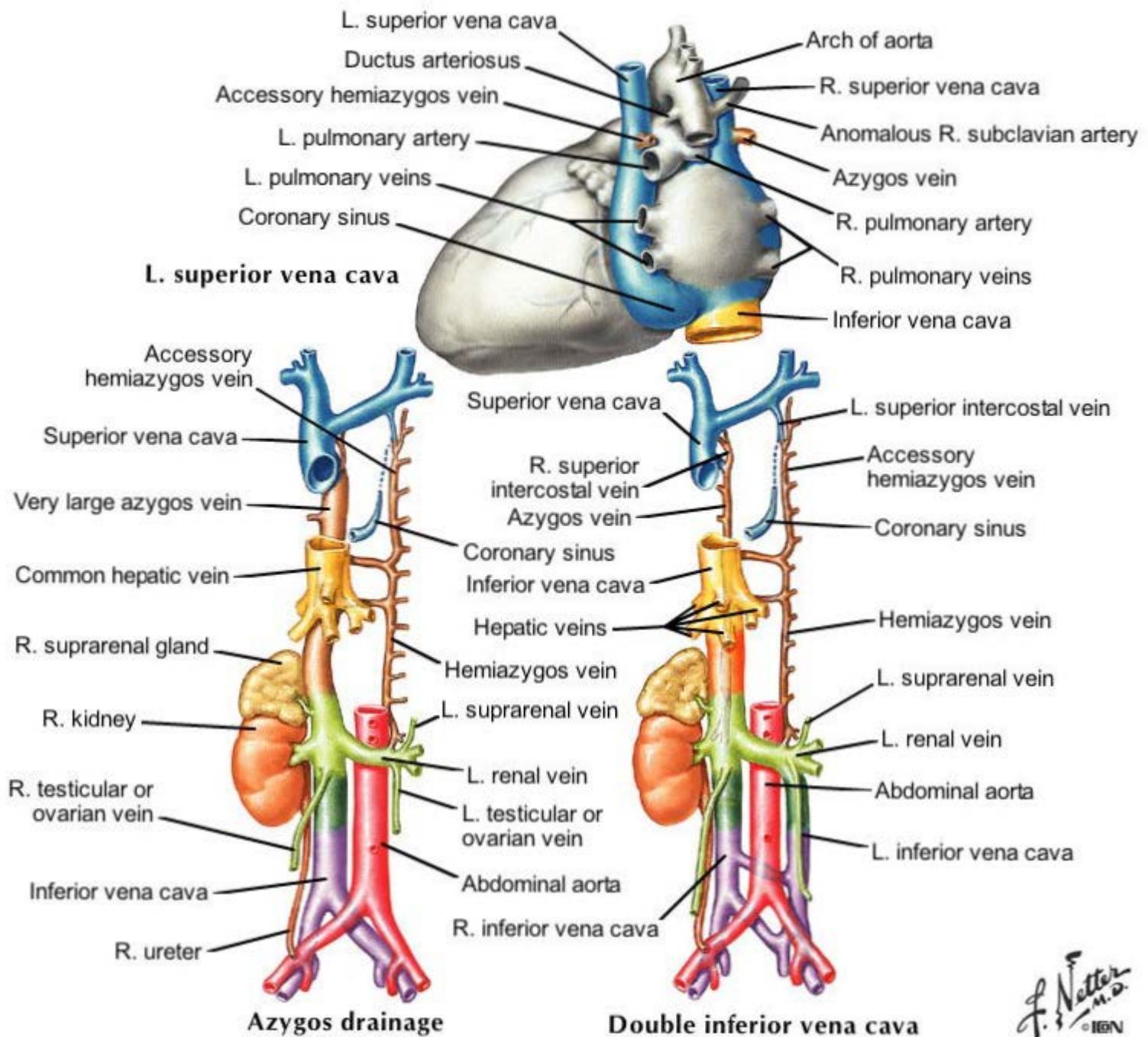


# Vein Development

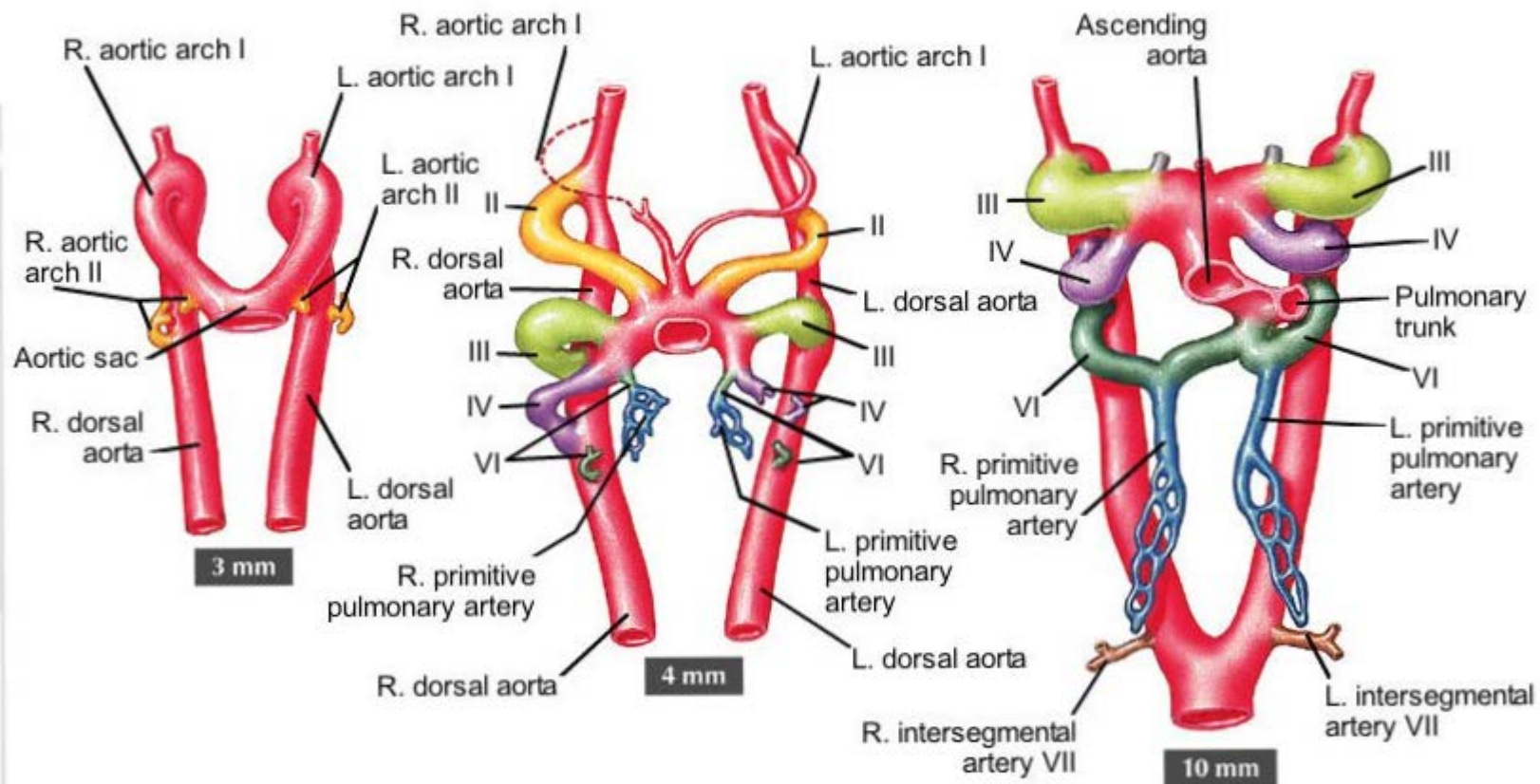




# Vein Anomalies

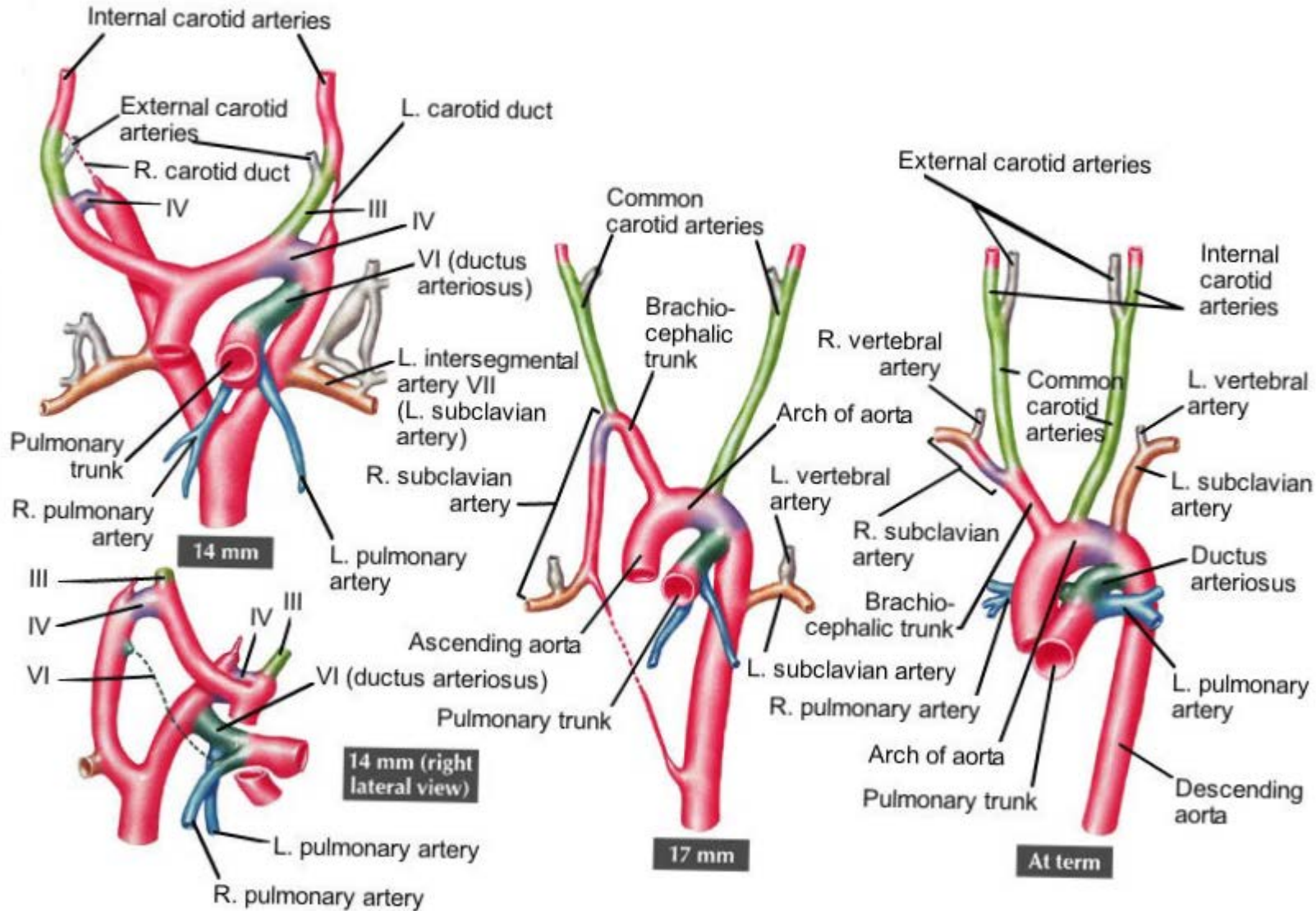


# Aortic Arch Arteries





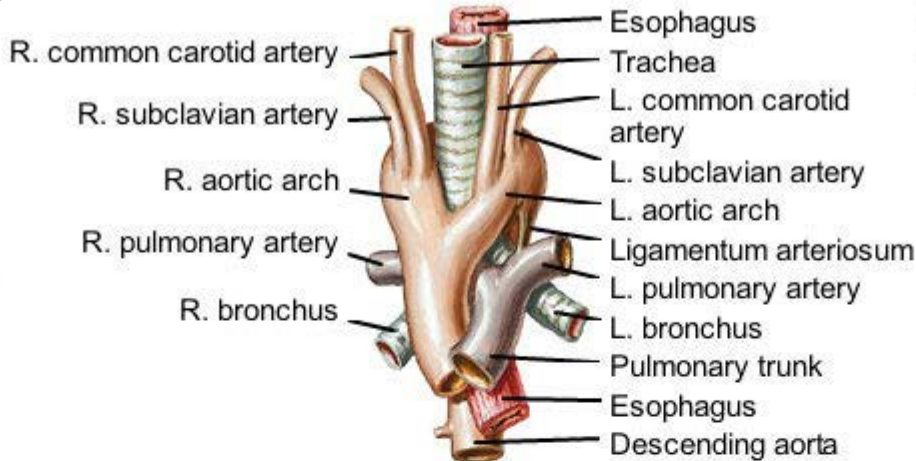
# Aortic Arch Arteries



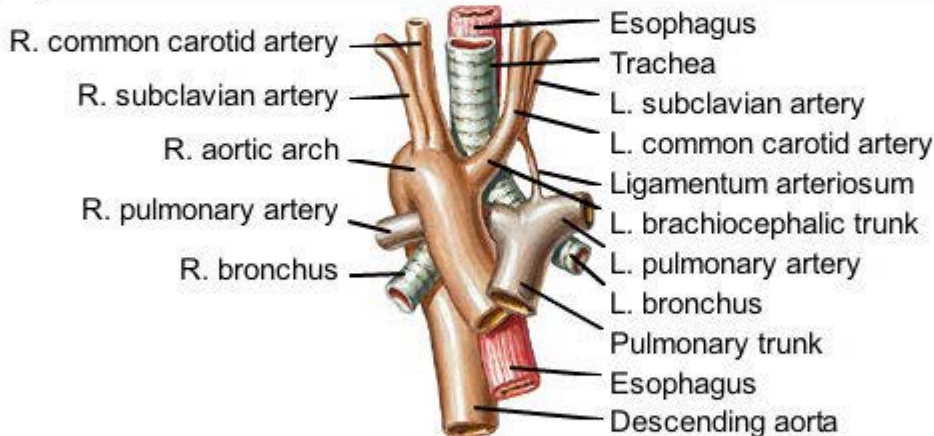
# Artery Anomalies

Embryologic origins:  
Compare colors with the  
sequence on Figure 4.05A  
and Figure 4.05B

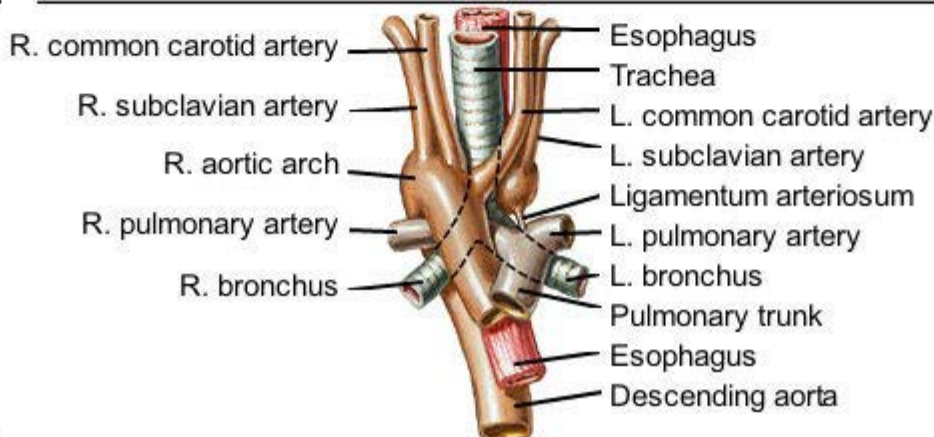
Double  
aortic  
arch



Right aortic  
arch and left  
ductus  
arteriosus:  
anterior type



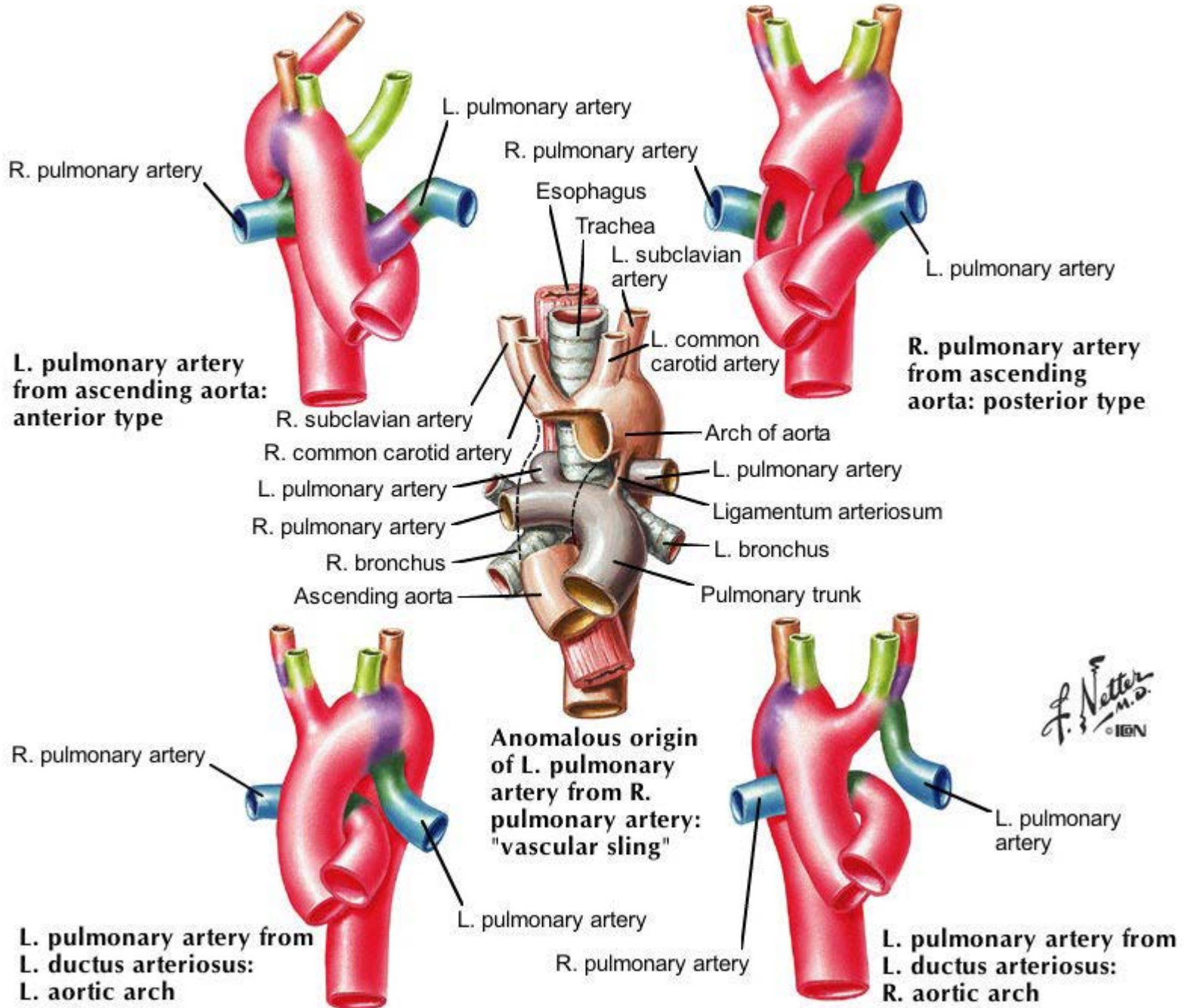
Right aortic  
arch and left  
ductus  
arteriosus:  
posterior  
type



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M.D.  
© IGV

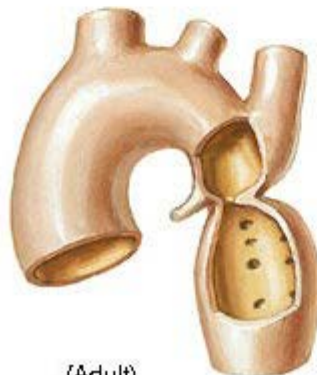
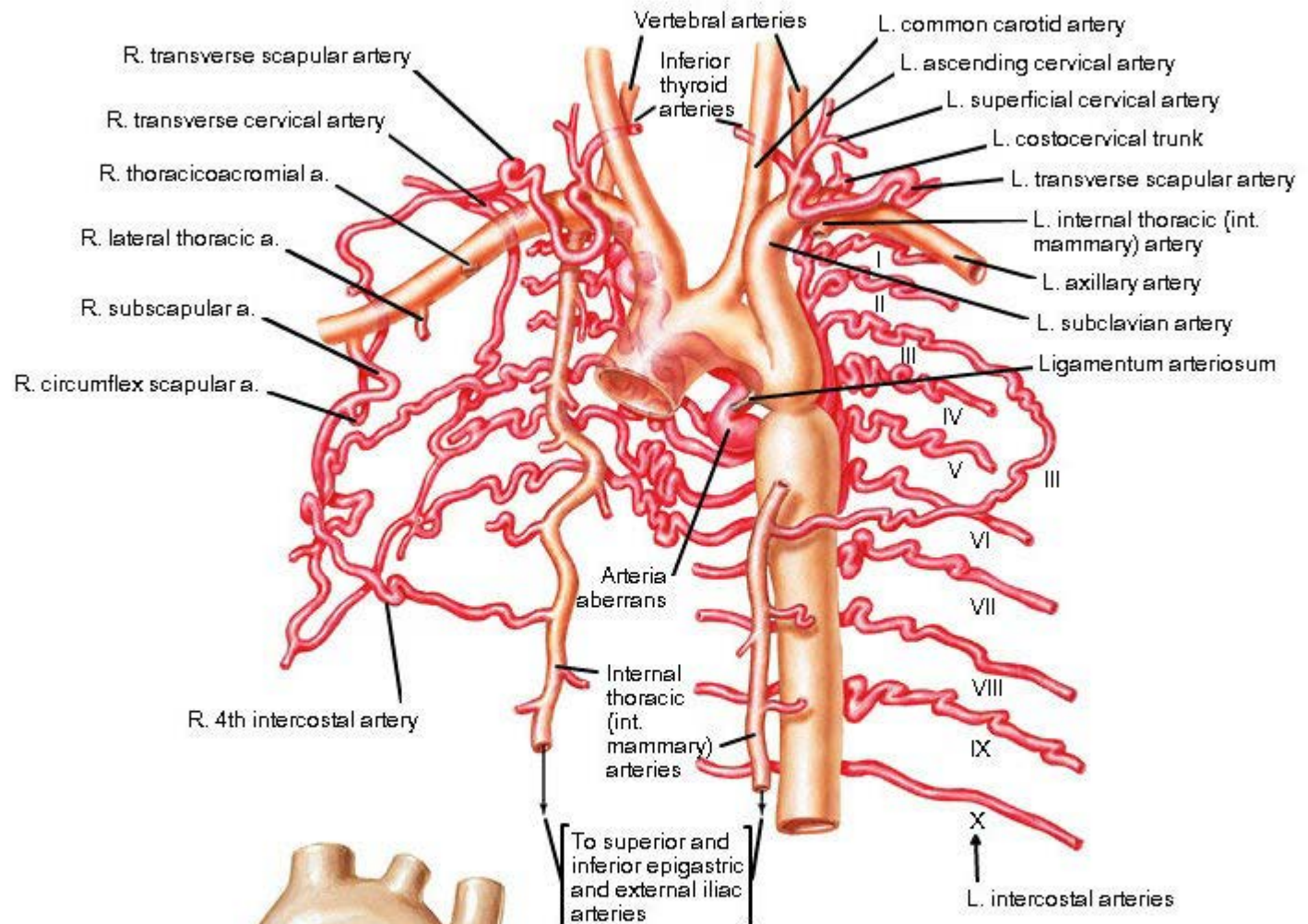


# Artery Anomalies



# Intersegmental Arteries and Coarctation of the Aorta

## Coarctation of the aorta



(Adult)  
Postductal type



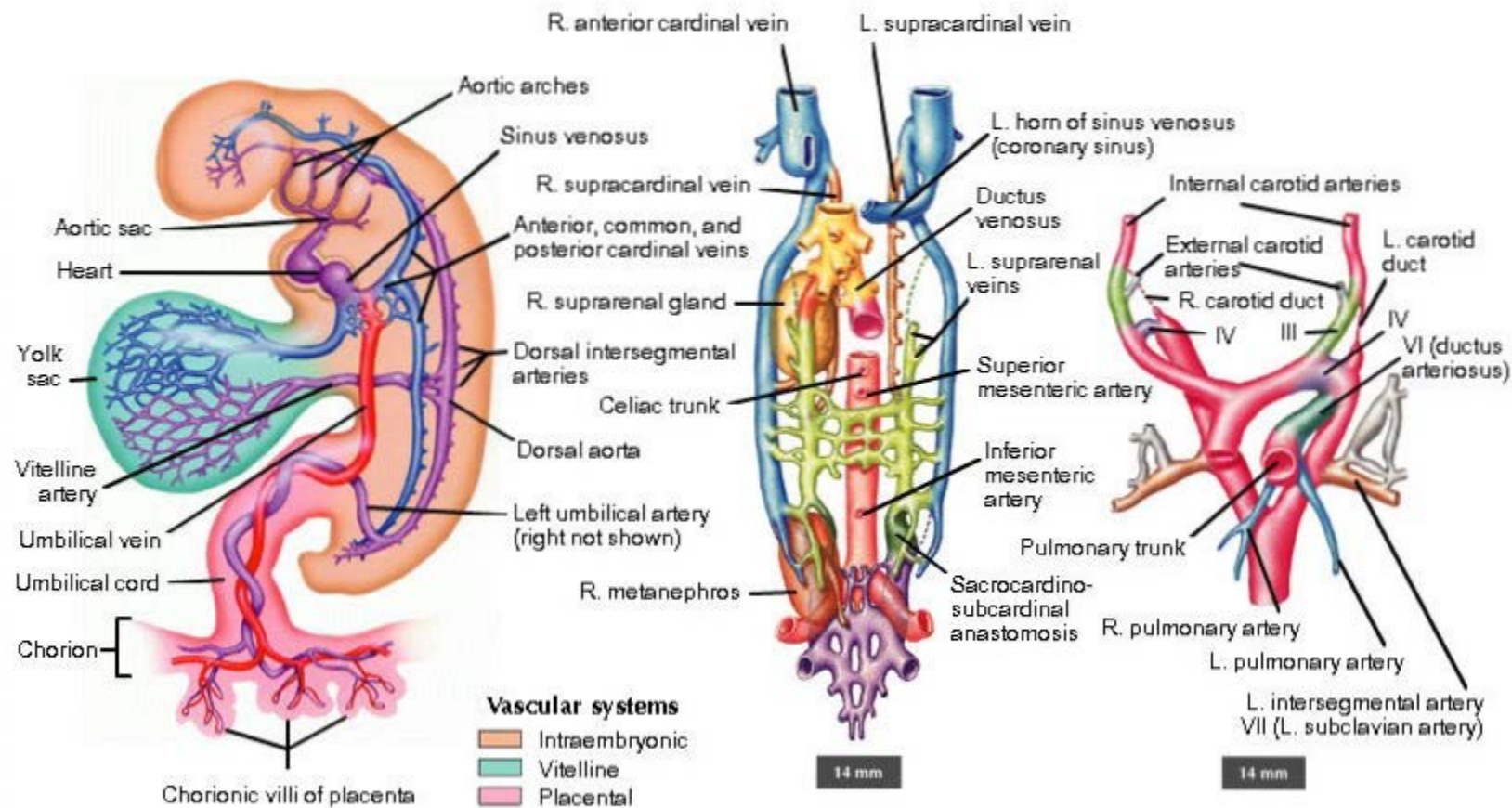
(Infant; 1 month)  
Preductal type



Intercostal artery retracted from rib,  
demonstrating erosion of costal  
groove by the tortuous vessel

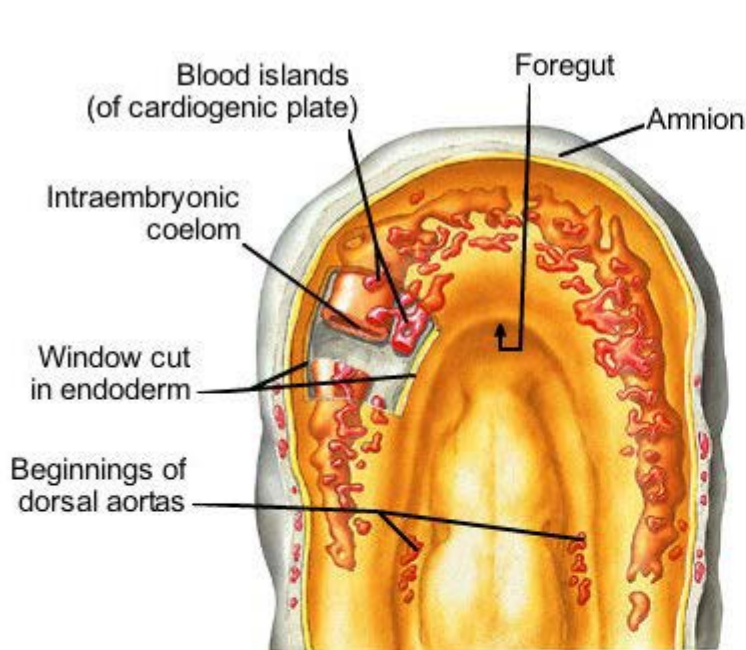


# Summary of Embryonic Blood Vessel Derivatives

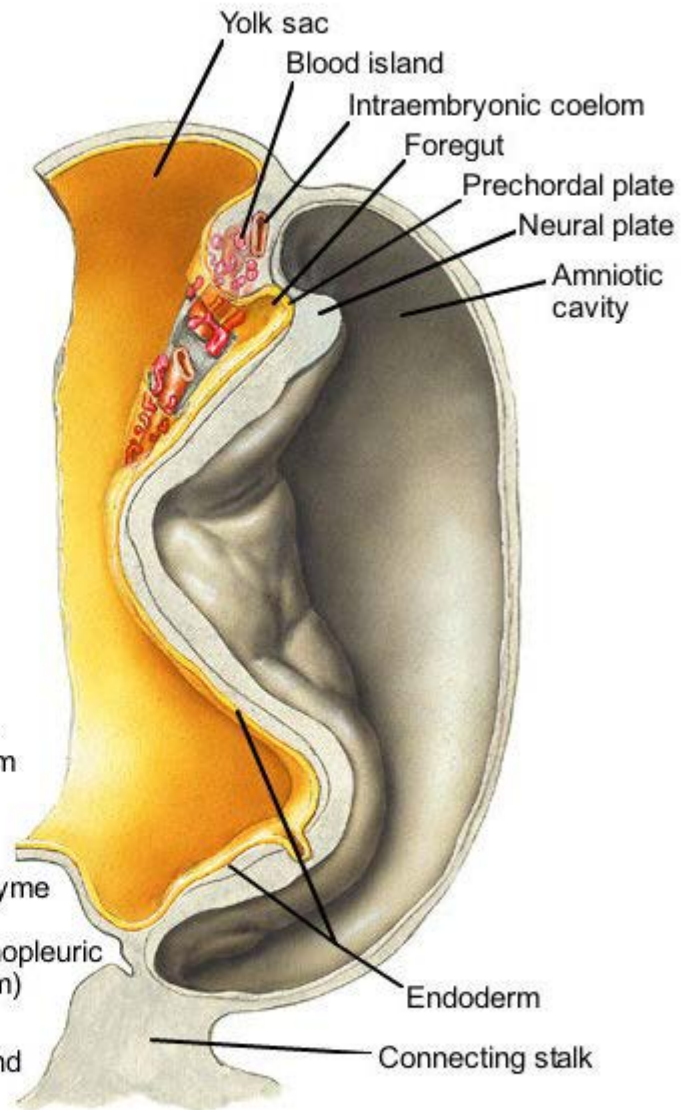


# Formation of Blood Vessels

Presomite stage (1.5-mm embryo) at approximately 20 days

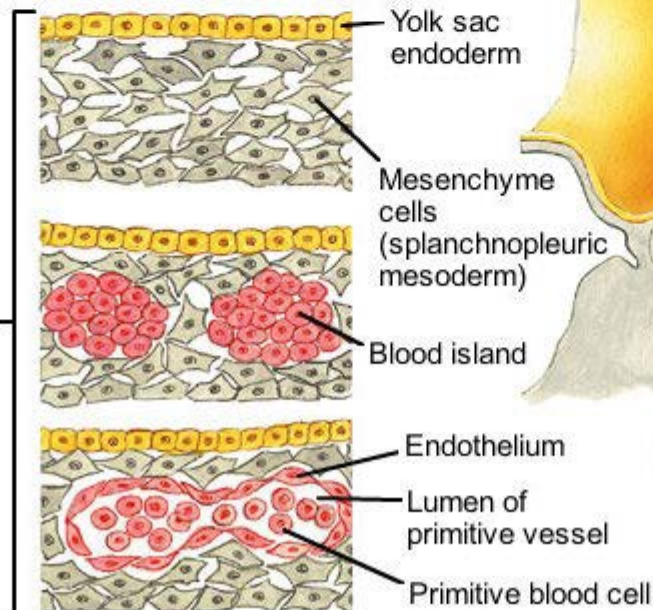


**Ventral dissection**



**Sagittal dissection (paramedian)**

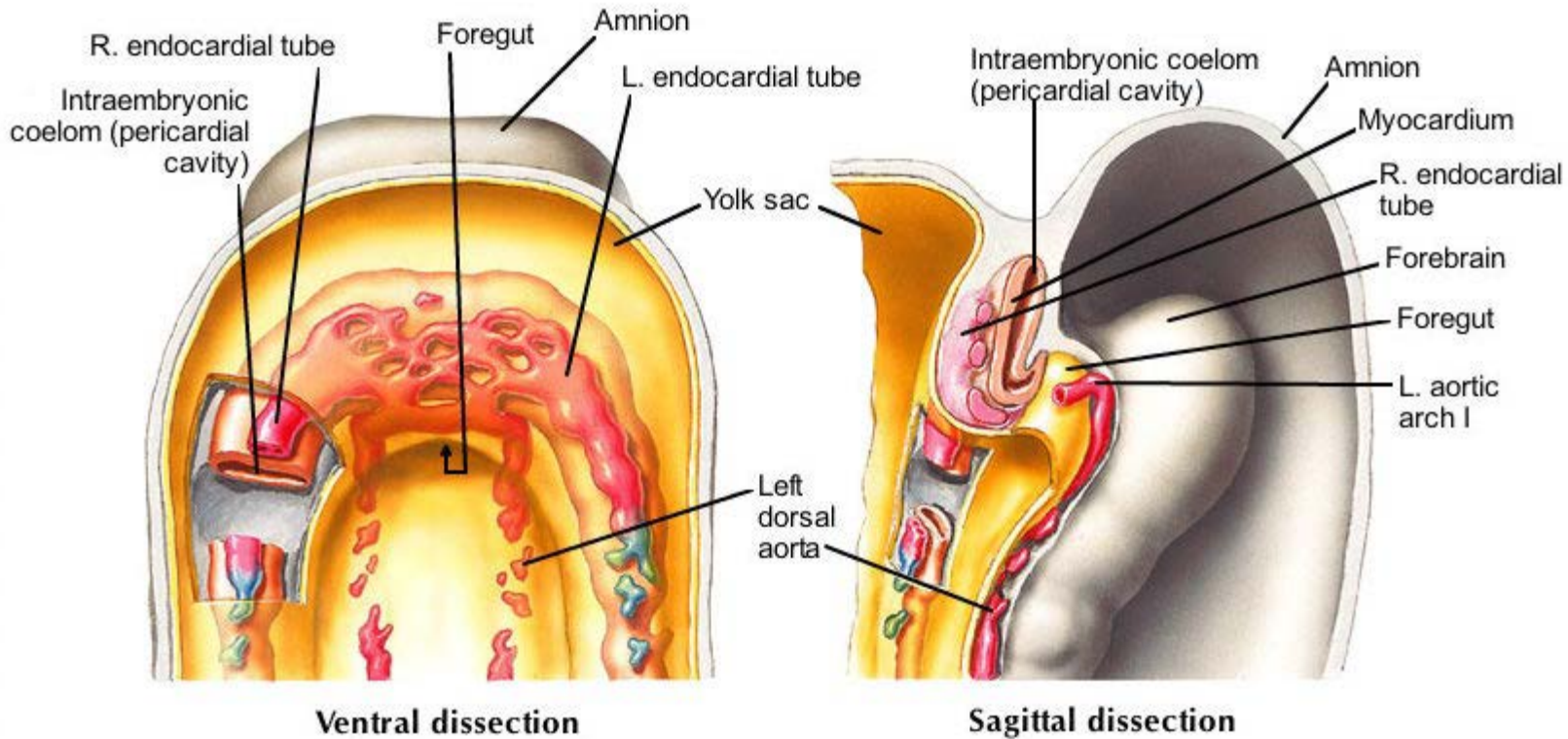
Progressive stages in blood vessel formation





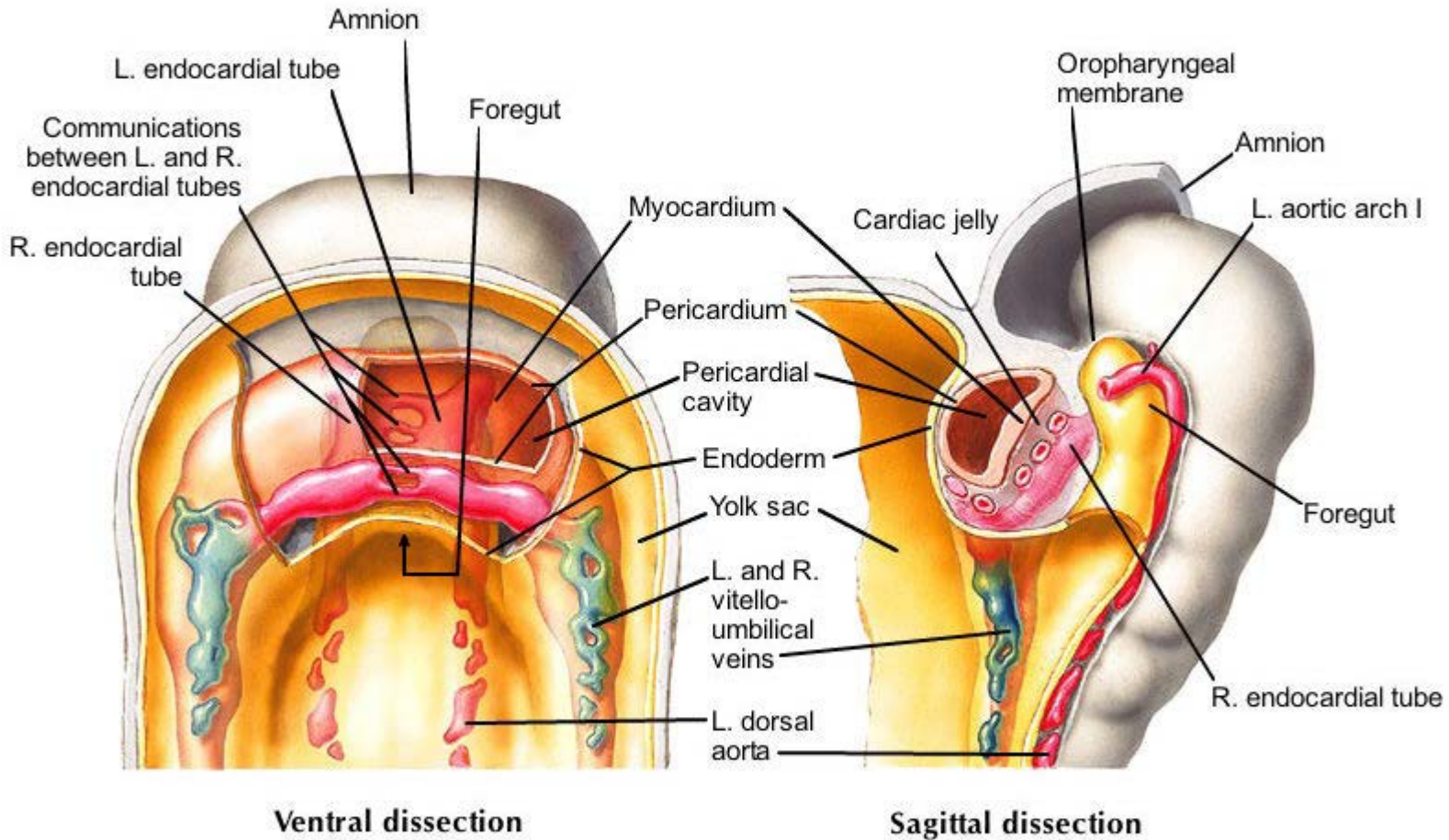
# Formation of the Heart Tube

One-somite stage (1.5 mm) at approximately 20 days



# Formation of the Heart Tube

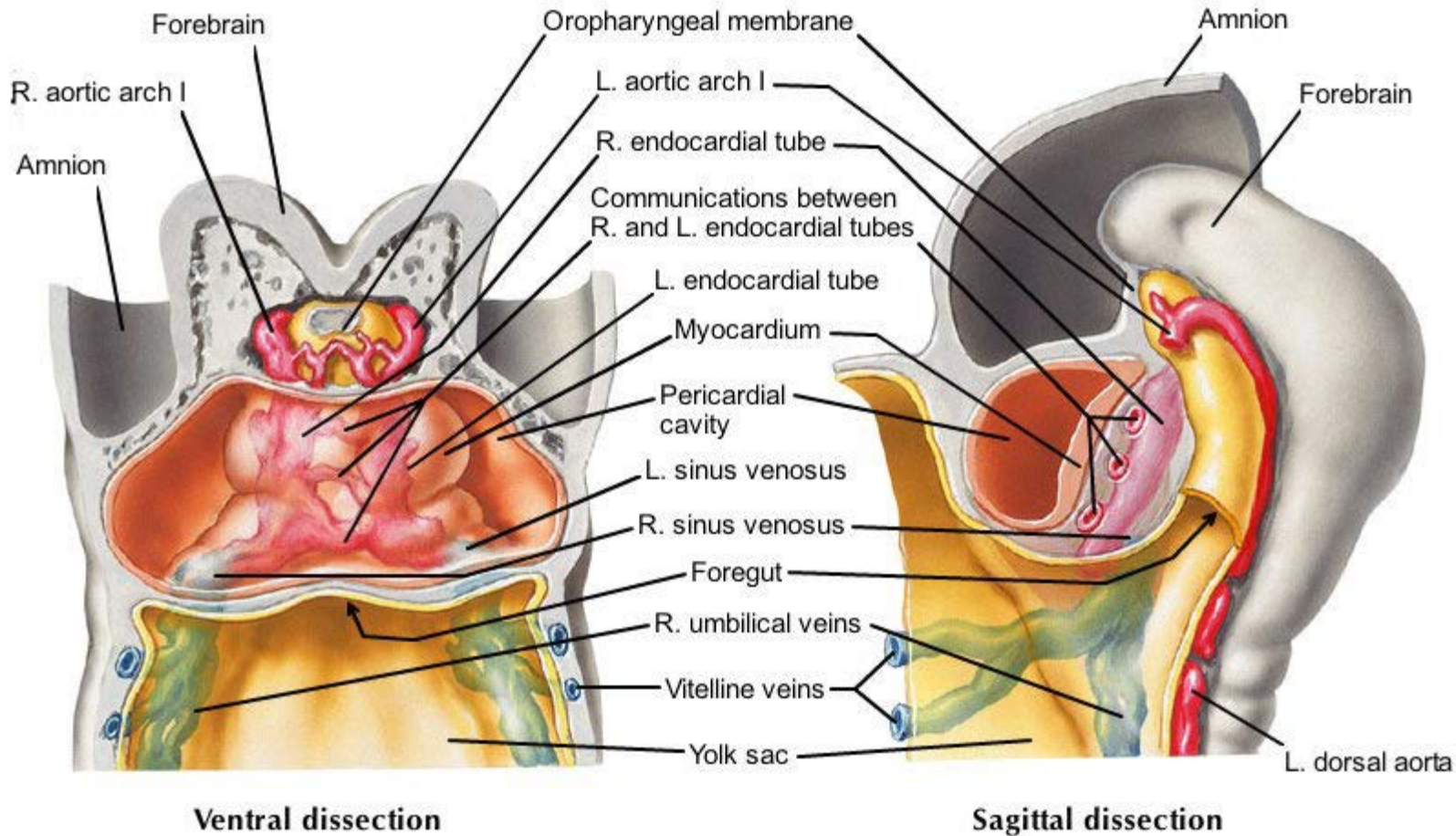
Two-somite stage (1.8 mm) at approximately 21 days





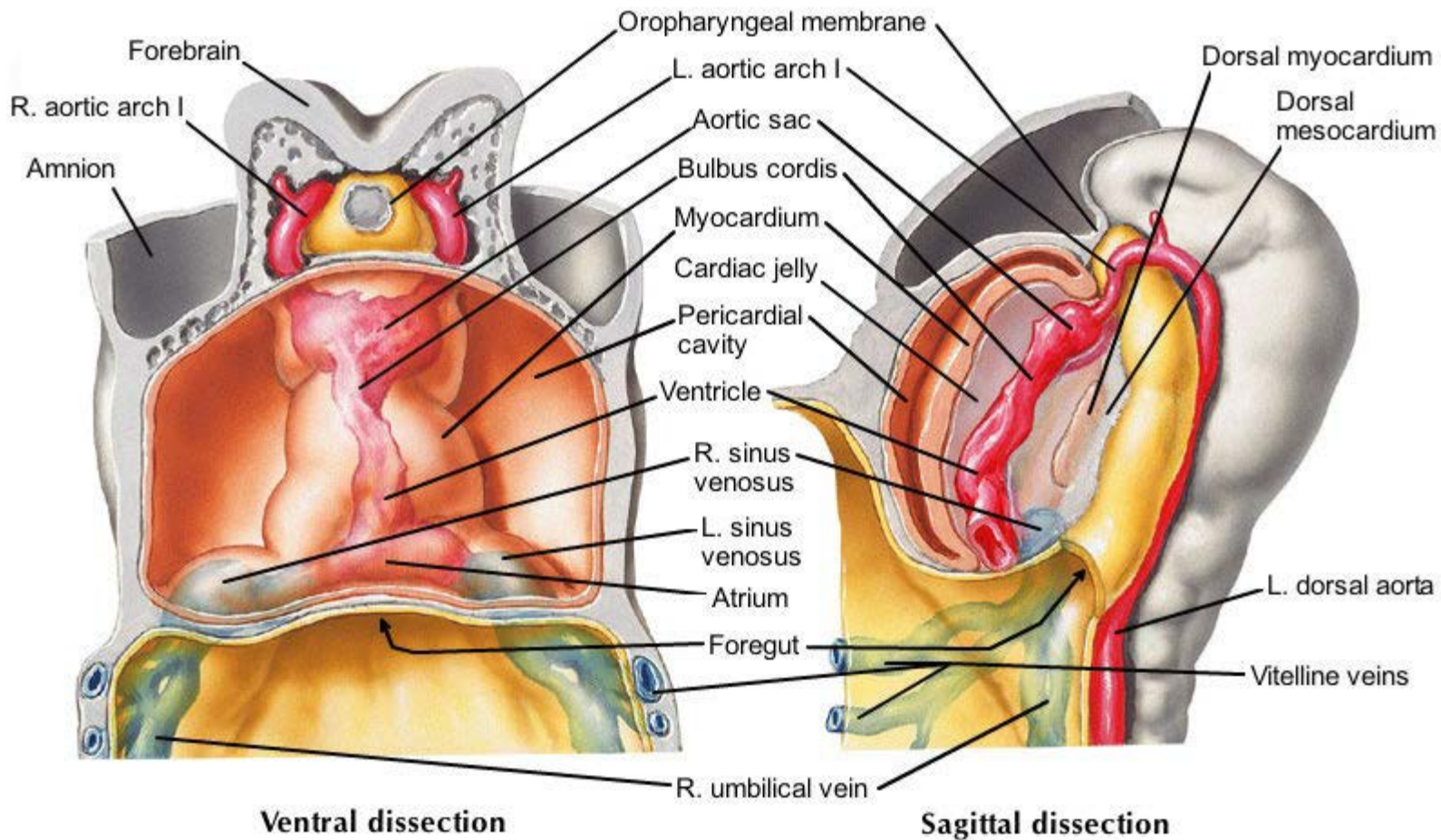
# Formation of the Heart Tube

Four-somite stage (2.0 mm) at approximately 22 days



# Formation of the Heart Tube

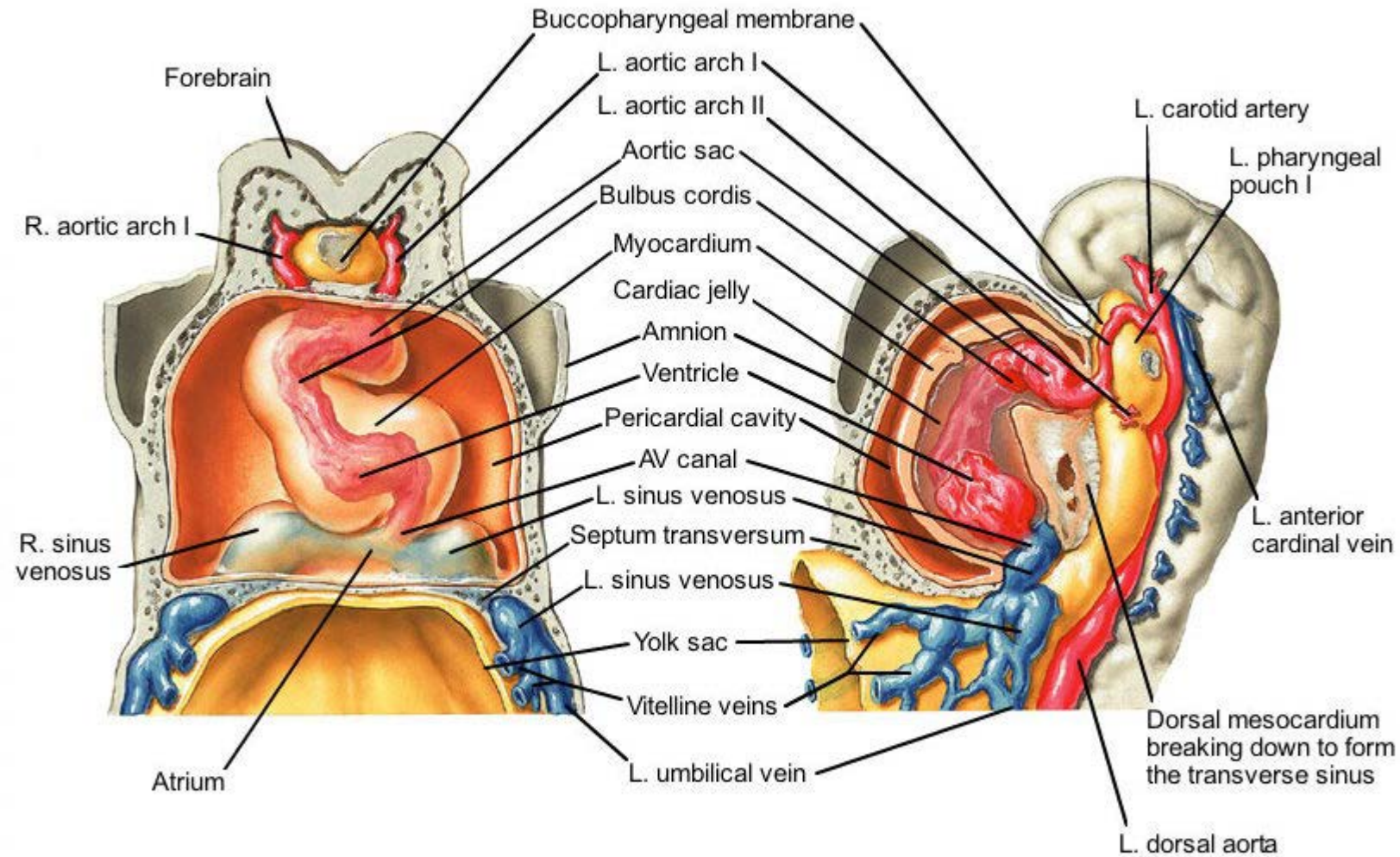
Seven-somite stage (2.2 mm) at approximately 23 days





# Chambers of the Heart Tube

Ten-somite stage (2.5 mm) at approximately 23 days

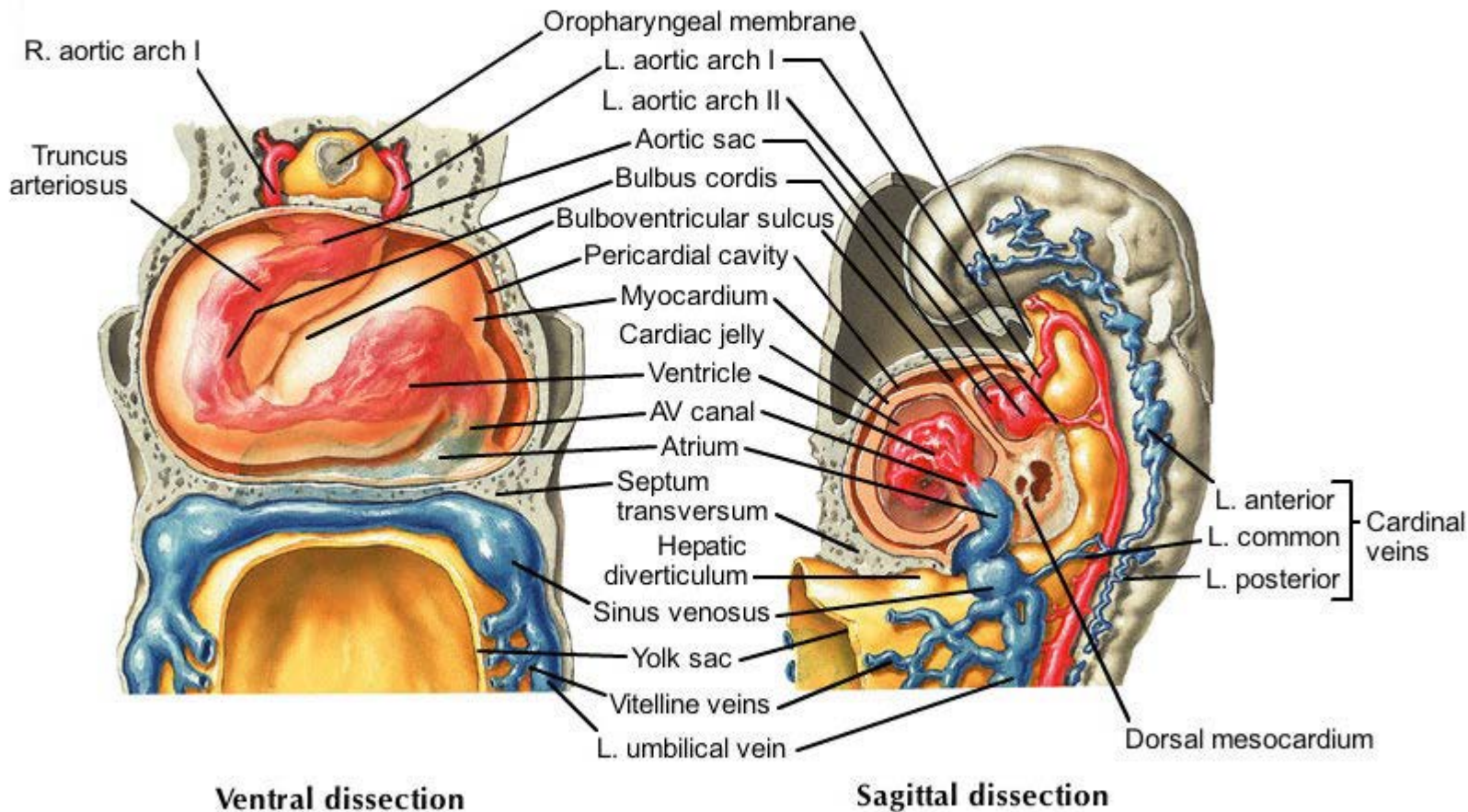


Ventral dissection

Sagittal dissection

# Chambers of the Heart Tube

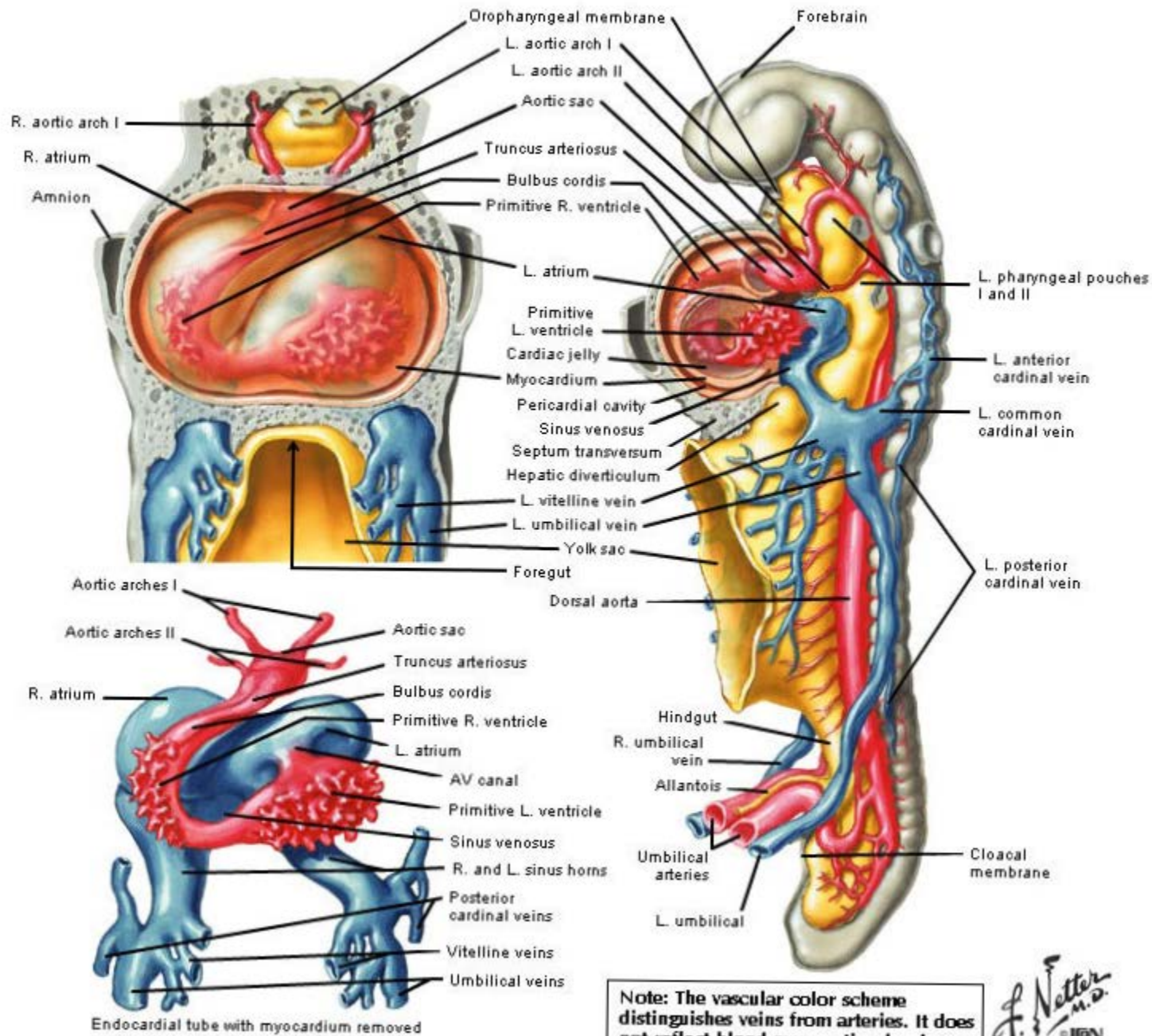
Fourteen-somite stage (3.0 mm) at approximately 24 days





# Bending of the Heart Tube

Twenty-somite stage (3.2 mm) at approximately 25 days



Note: The vascular color scheme distinguishes veins from arteries. It does not reflect blood oxygenation levels.

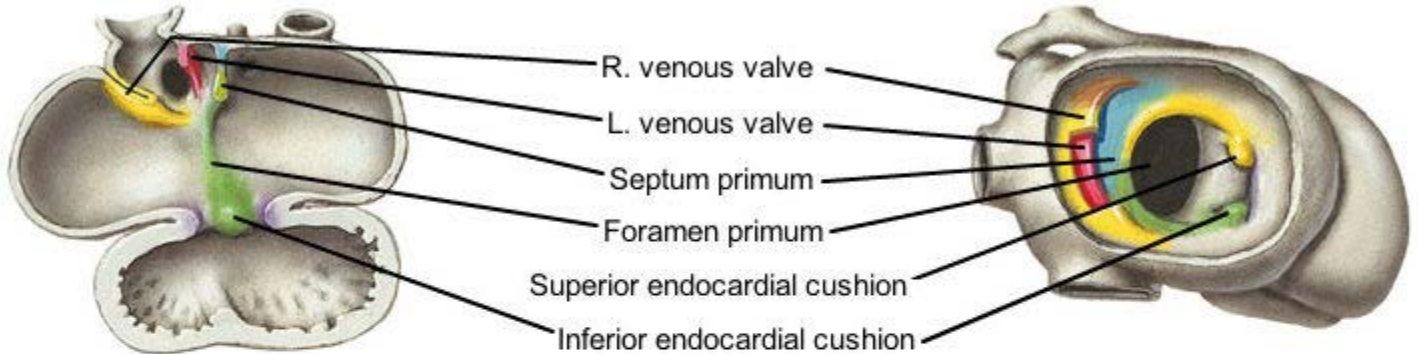
F. Netter  
M.D.  
© IEN

# Partitioning the Heart Tube

Inferior halves of heart  
viewed from above

Opened and viewed from right side

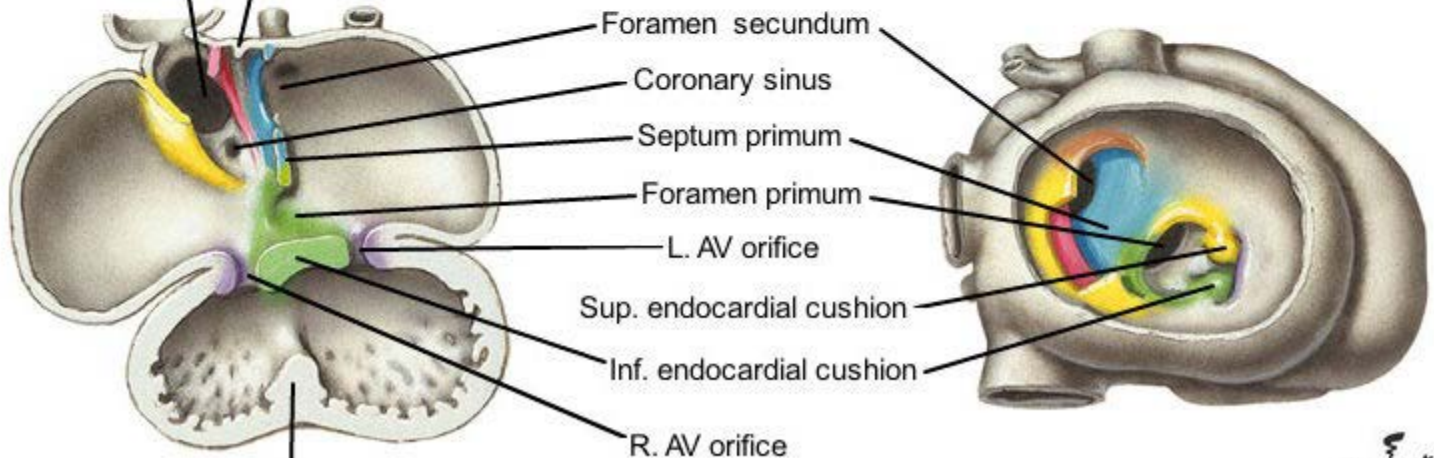
(Segment removed from R. venous  
valve to expose L. venous valve)



**6.5 mm (29 days)**

Inferior vena cava

Septum secundum

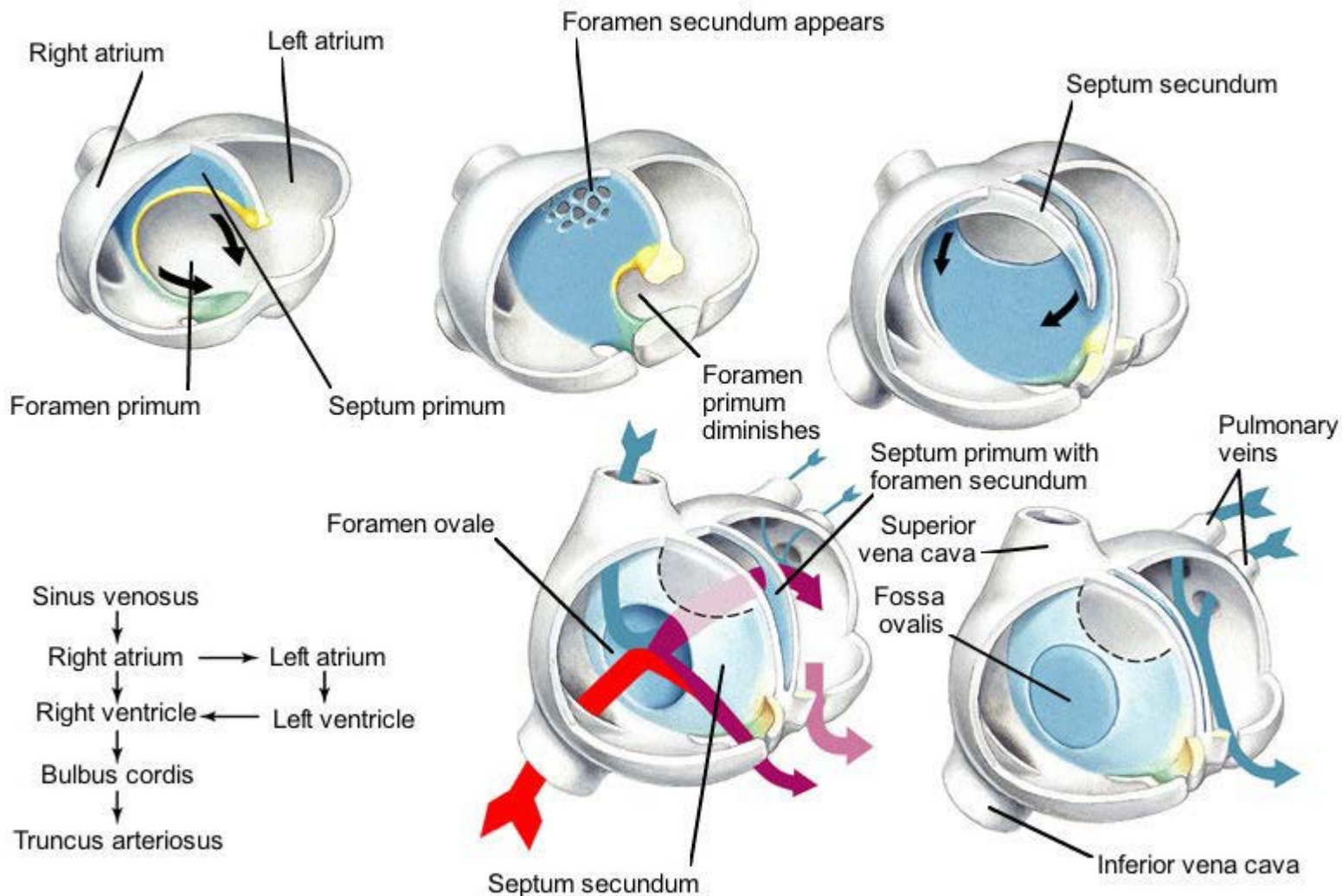


Interventricular septum

**9 mm (33 days)**



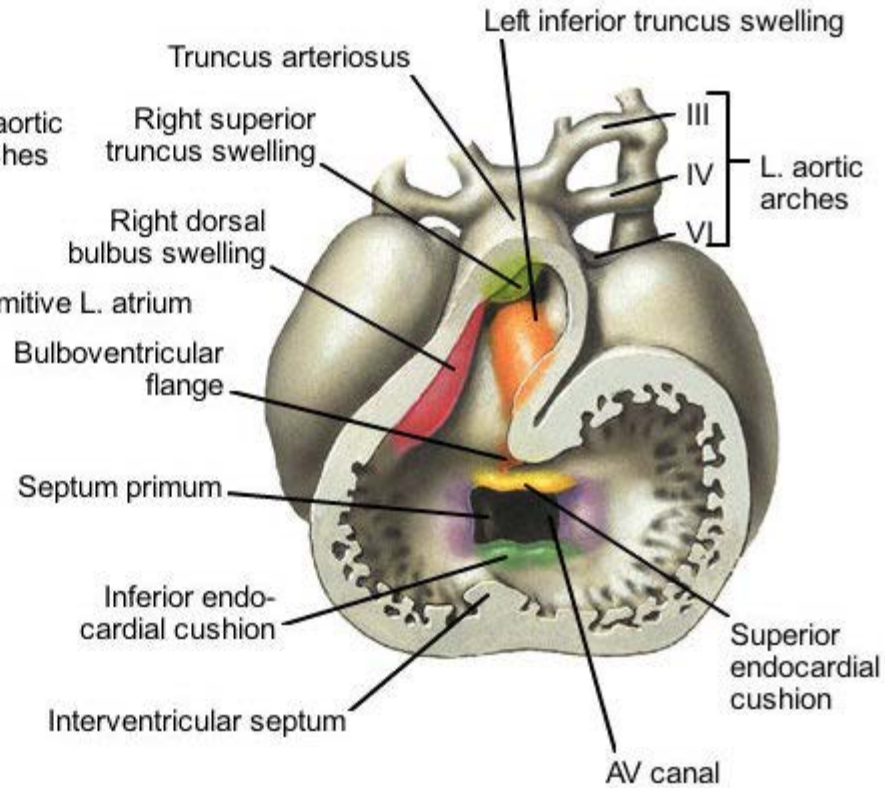
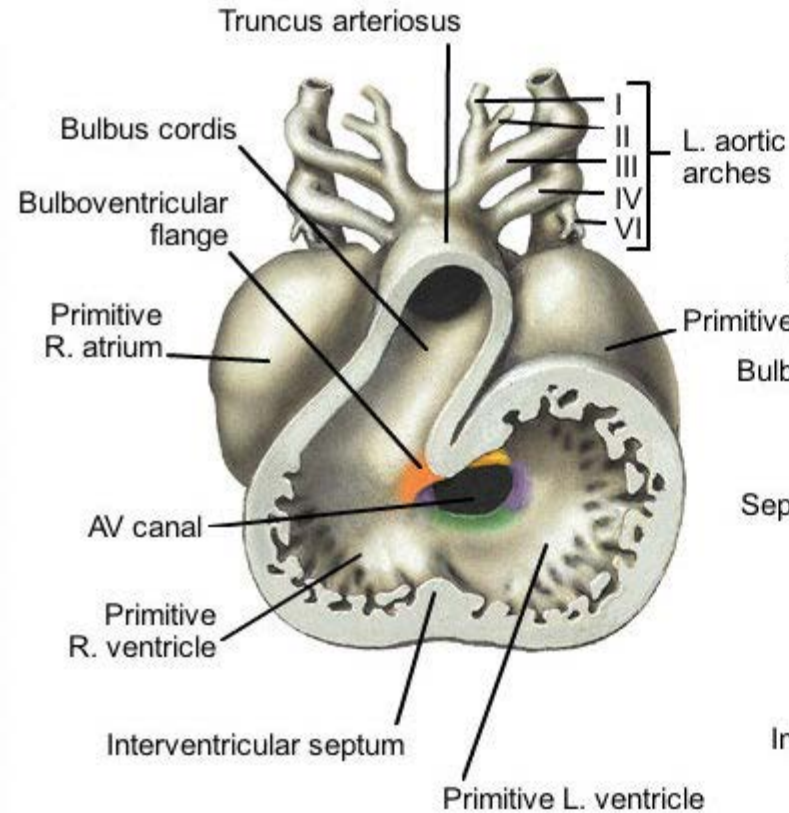
# Atrial Separation



# Spiral (Aorticopulmonary) Septum

4 to 5 mm (approximately 27 days)

6 to 7 mm (approximately 29 days)

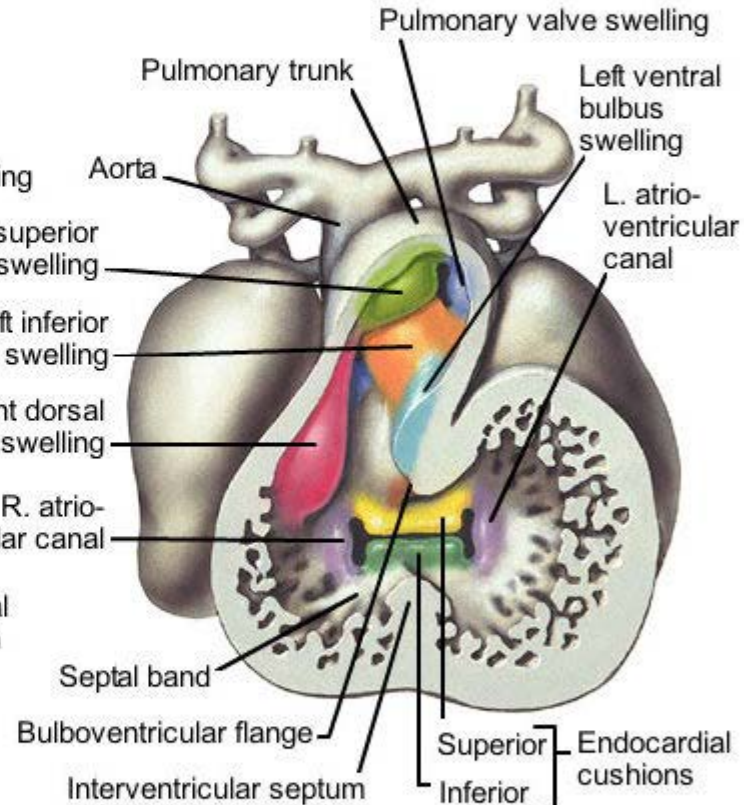
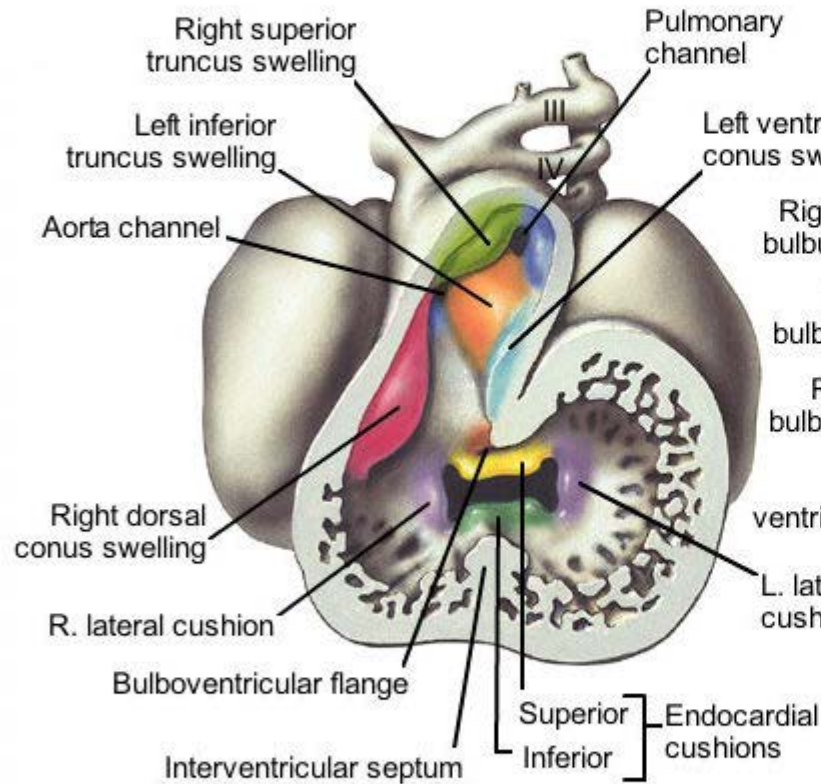




# Spiral (Aorticopulmonary) Septum

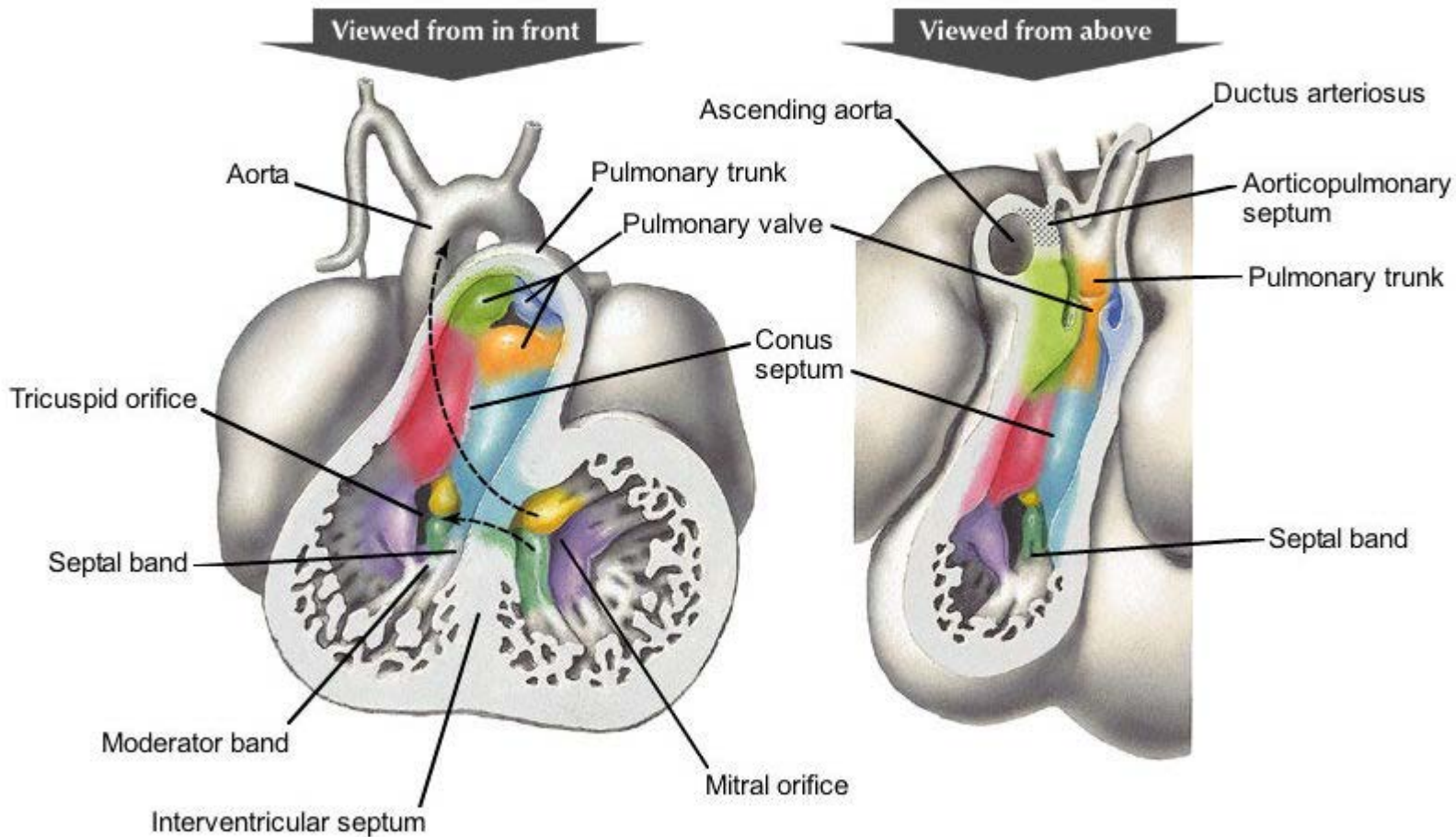
8 to 9 mm (approximately 31 days)

9 to 10 mm (approximately 33 days)



# Completion of the Spiral (Aorticopulmonary) Septum

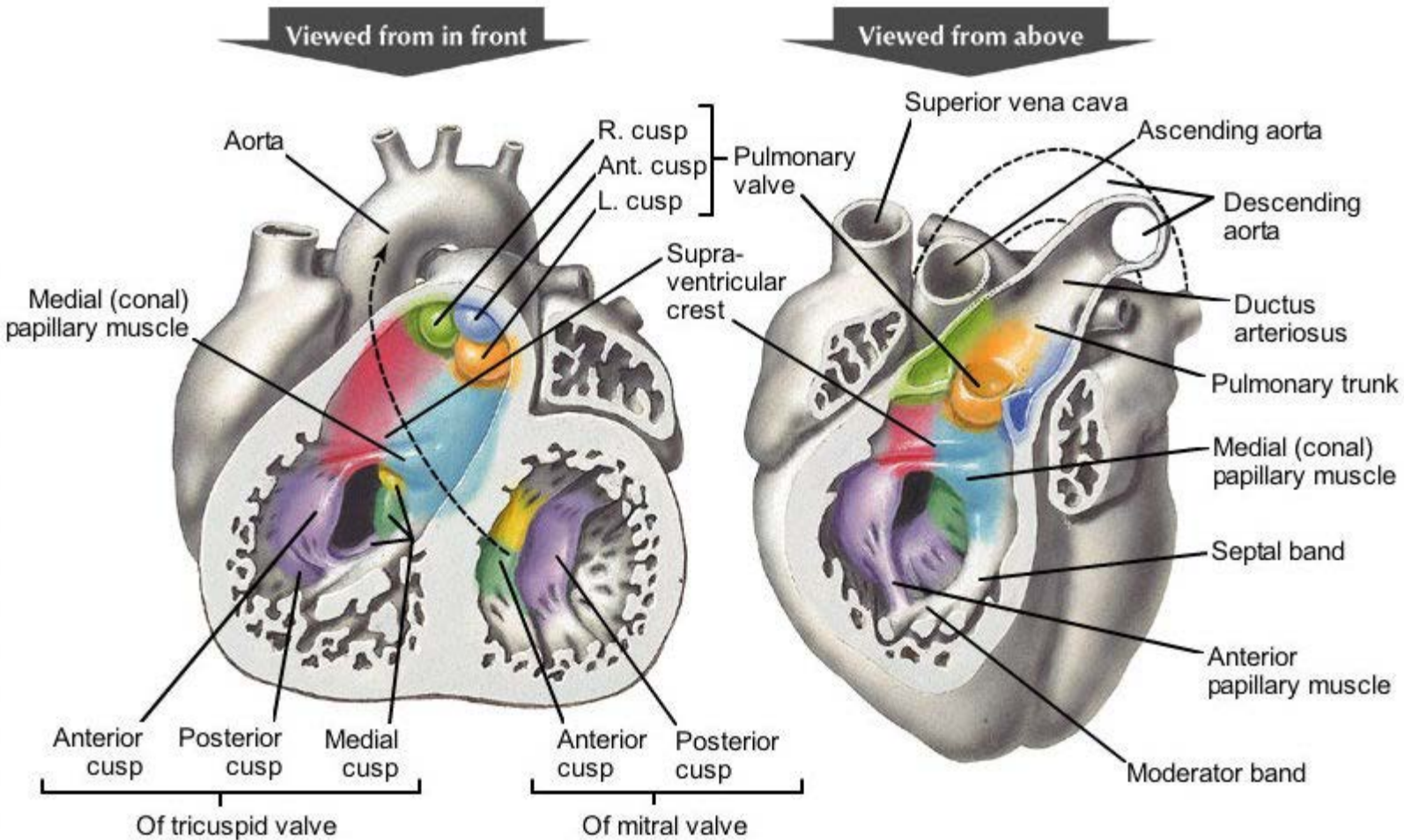
16 mm (approximately 37 days)





# Completion of the Spiral (Aorticopulmonary) Septum

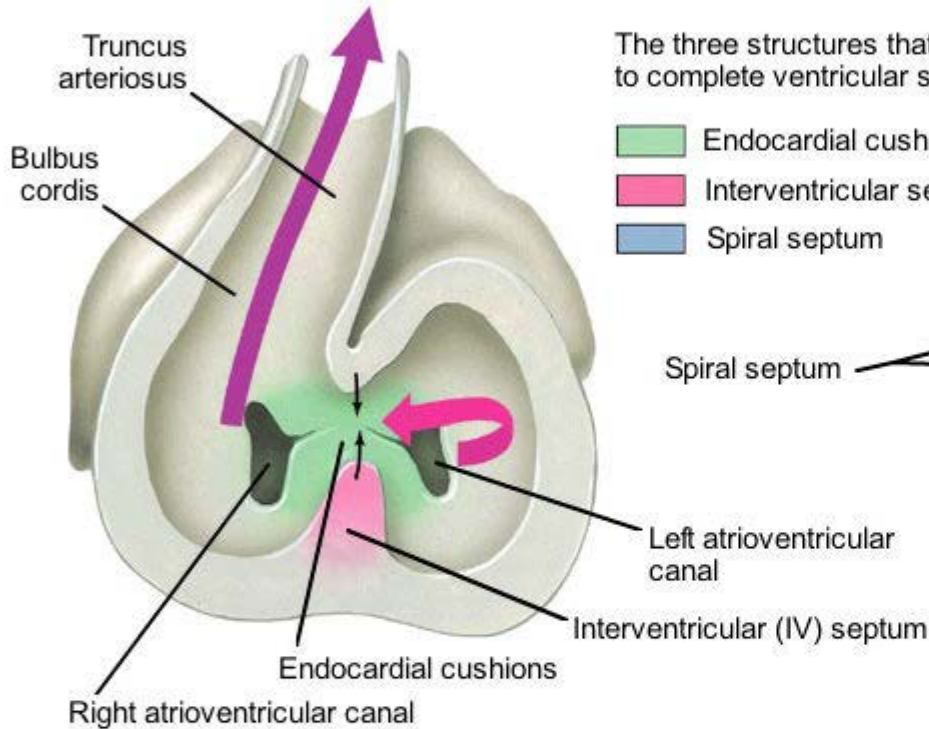
40 mm (approximately 55 days)



# Ventricular Separation and Bulbus Cordis

## Without the spiral septum

No exit for blood in left ventricle

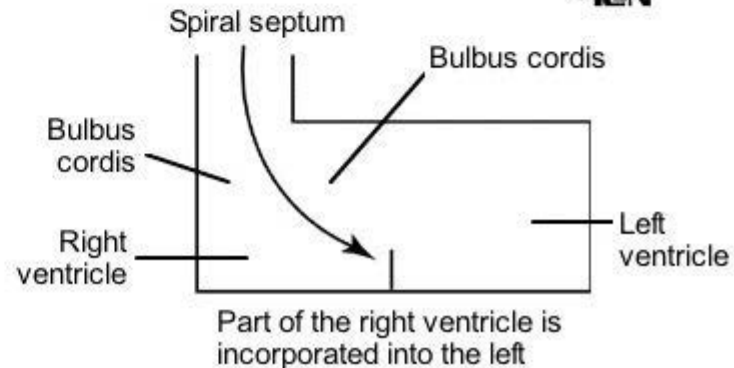
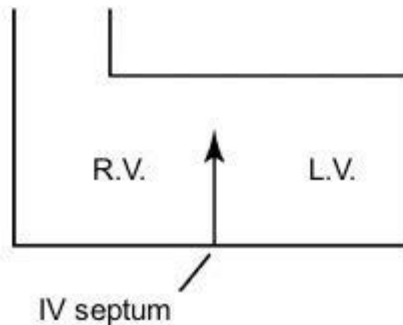
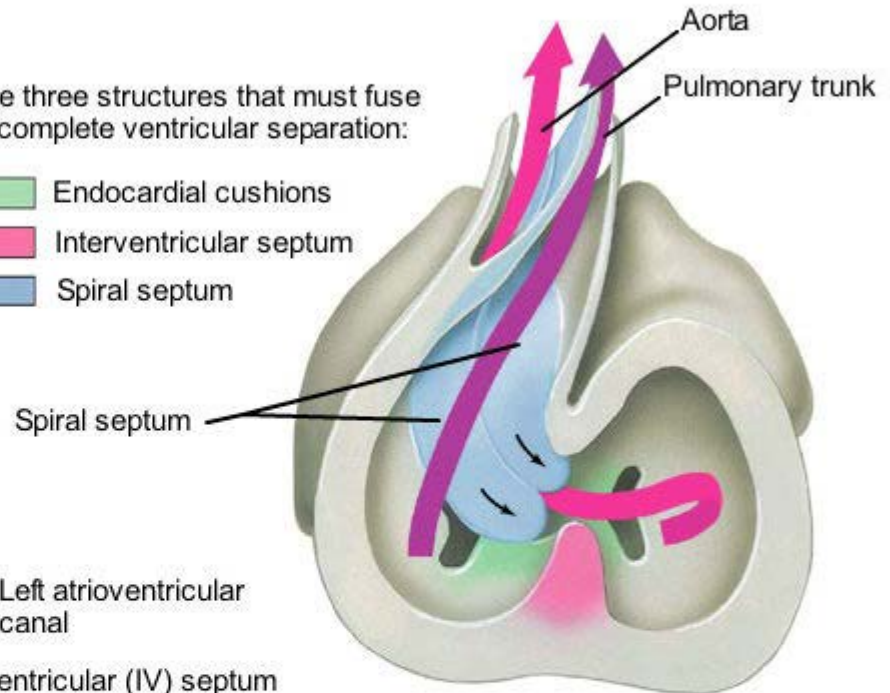


## With the spiral septum

Blood can exit both ventricles

The three structures that must fuse to complete ventricular separation:

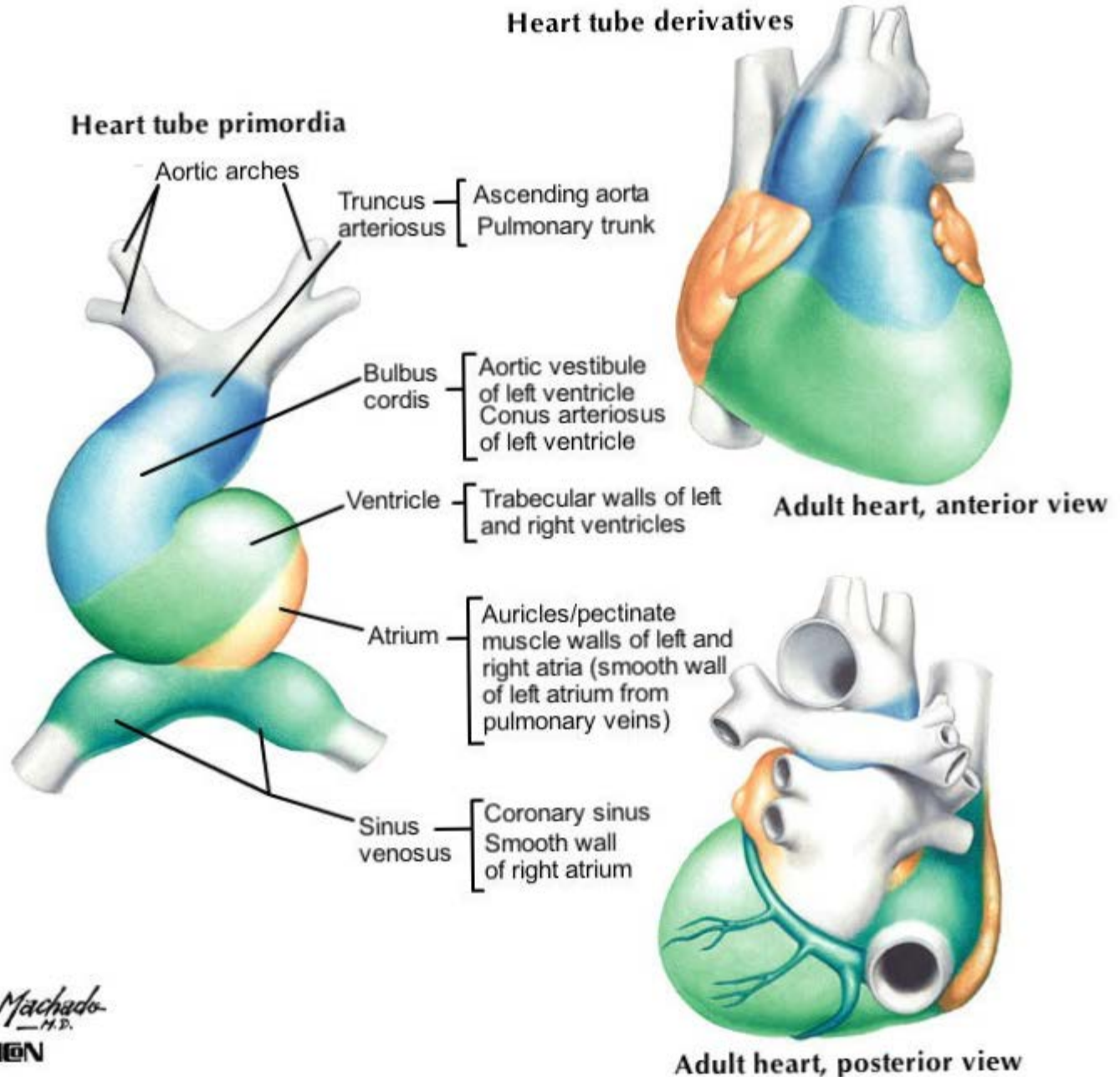
- Endocardial cushions
- Interventricular septum
- Spiral septum



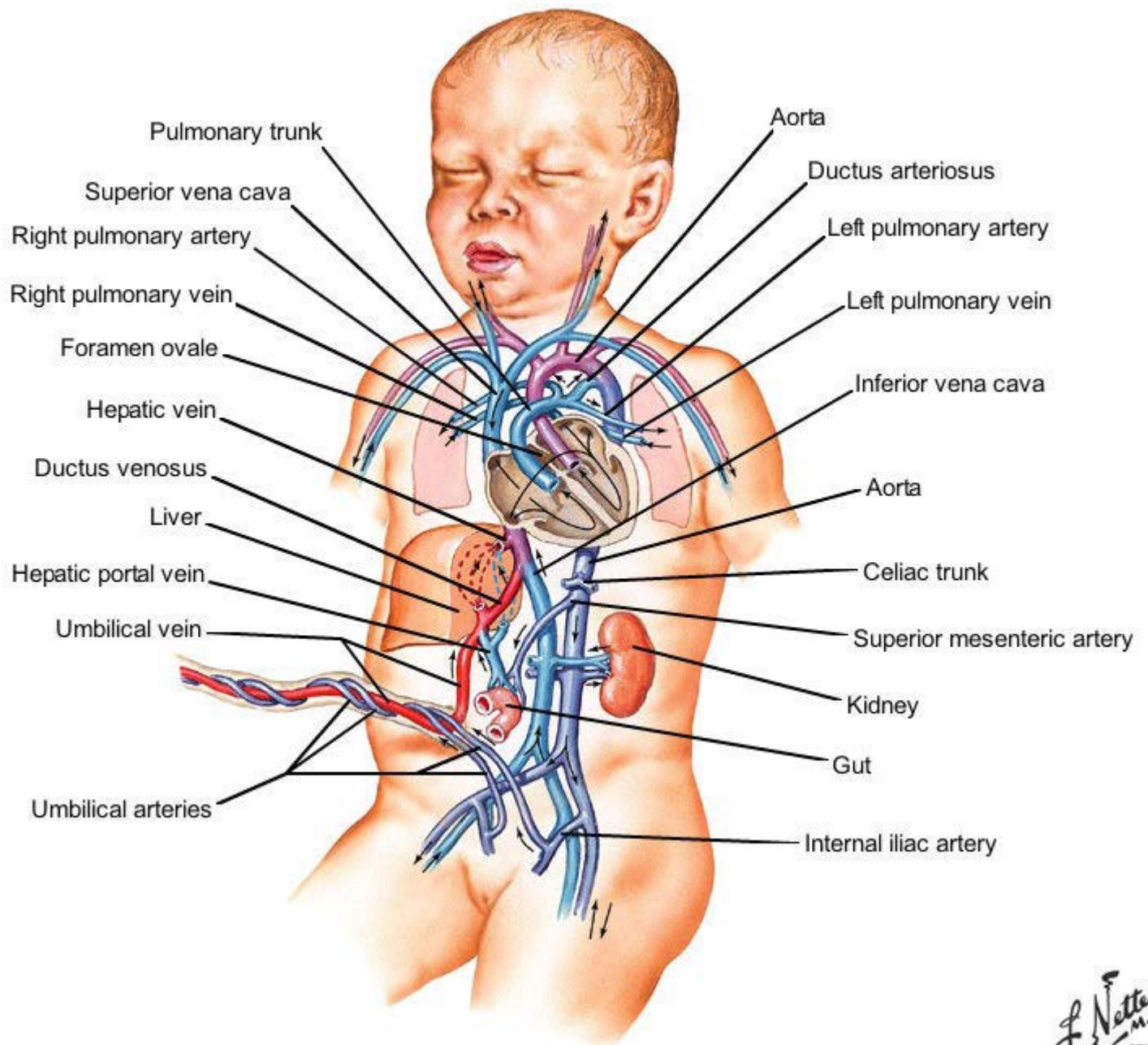
*C. Machado*  
M.D.  
© IGV



# Adult Derivatives of the Heart Tube Chambers

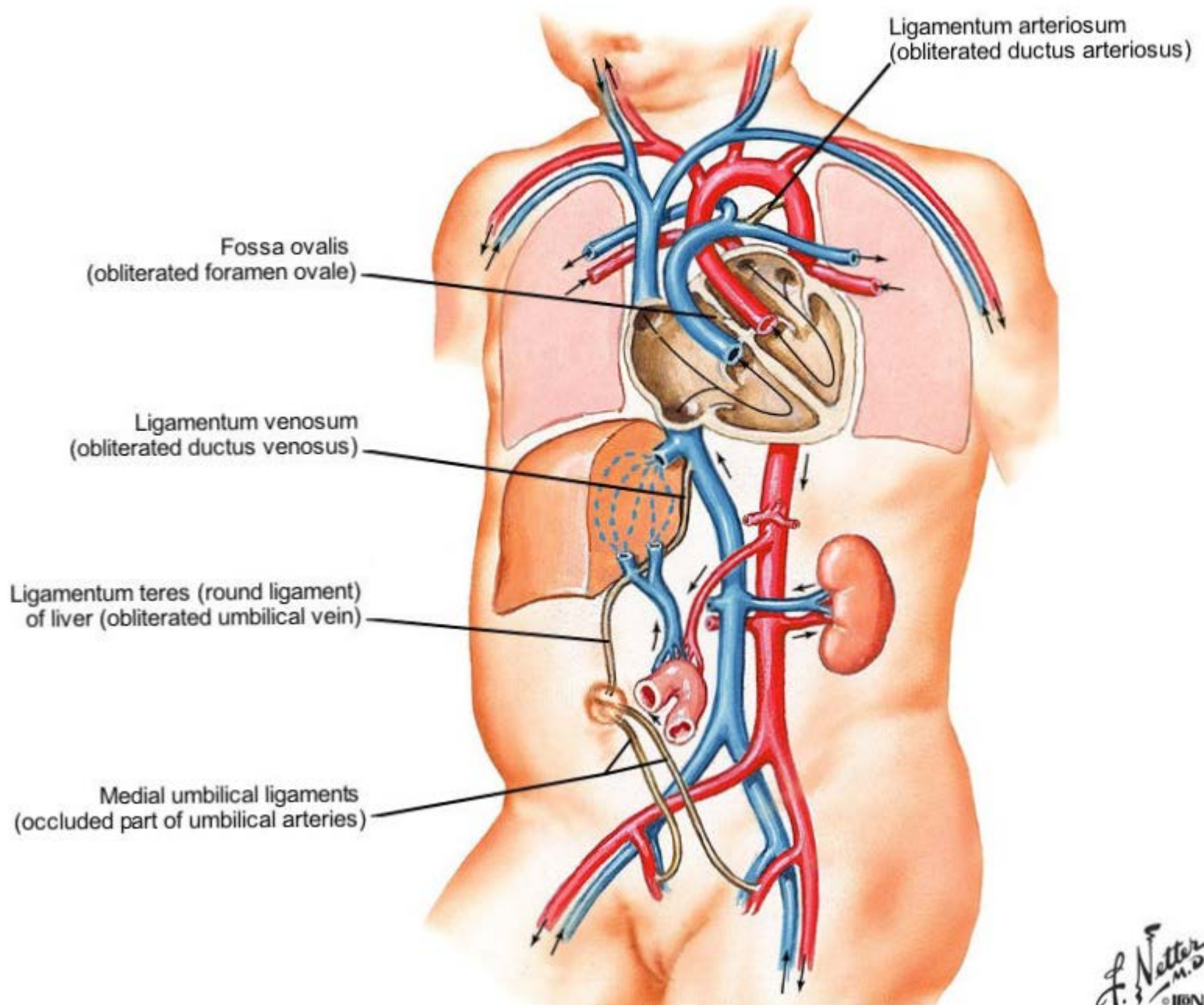


# Fetal Circulation



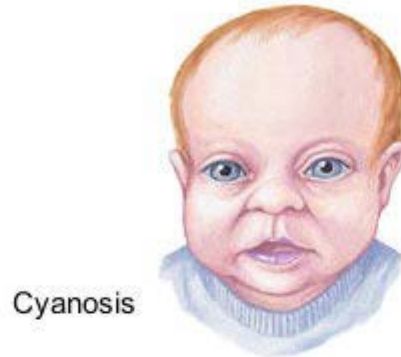


# Transition to Postnatal Circulation



# Congenital Heart Defect Concepts

## Clinical characteristics of too little pulmonary flow



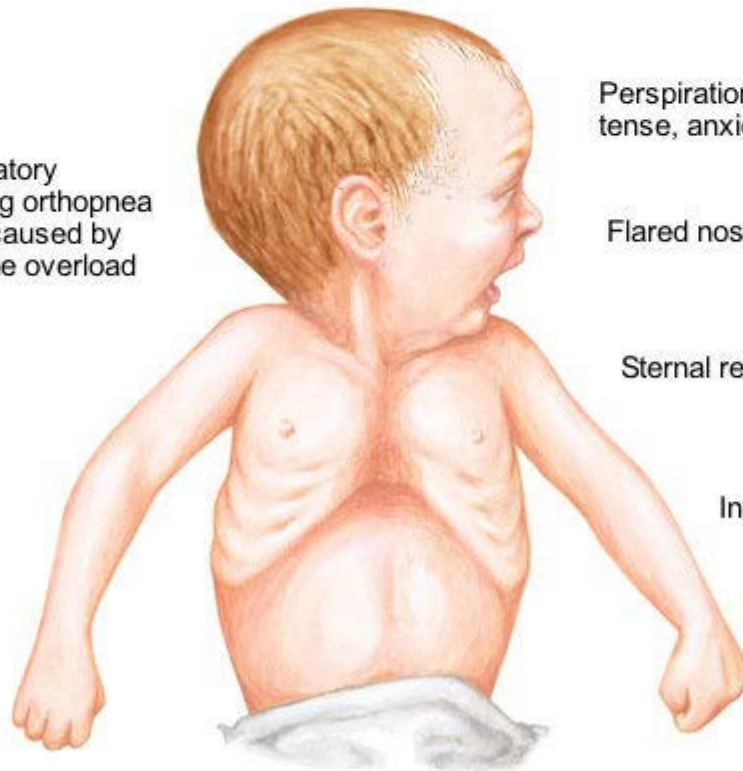
Cyanosis



Clubbing of fingers

## Clinical characteristics of too much pulmonary flow (pulmonary volume overload)

Infant with respiratory distress (including orthopnea and tachypnea) caused by pulmonary volume overload



Perspiration and tense, anxious facies

Flared nostrils

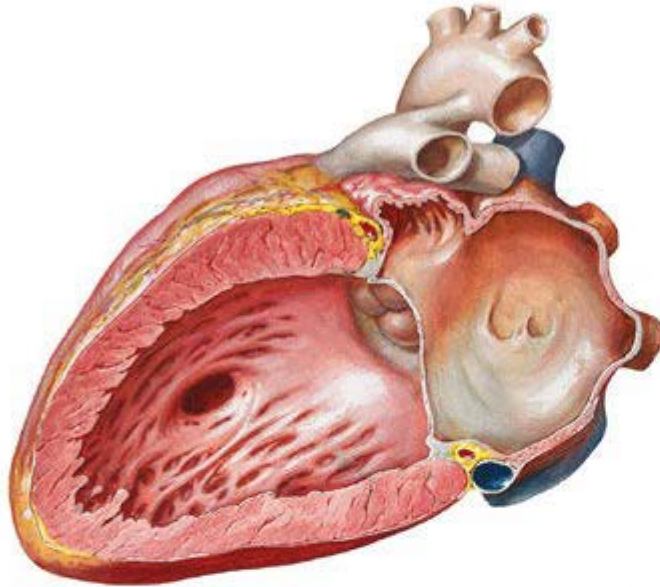
Sternal retraction

Intercostal retractions

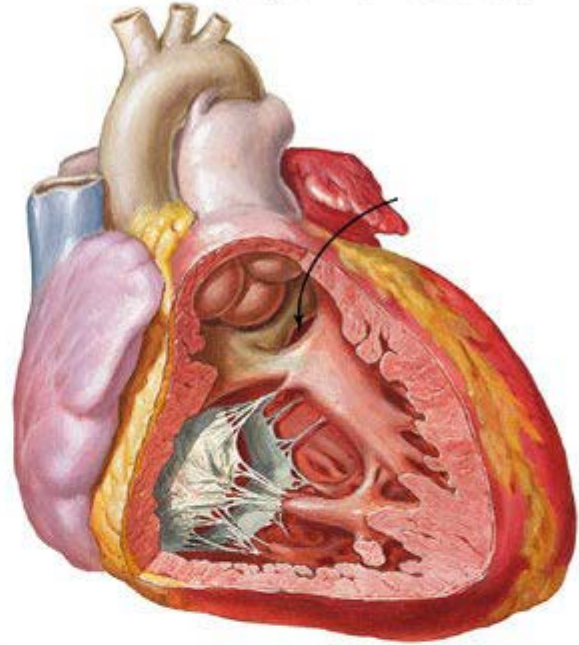


# Ventricular Septal Defects

Muscular interventricular septal defect

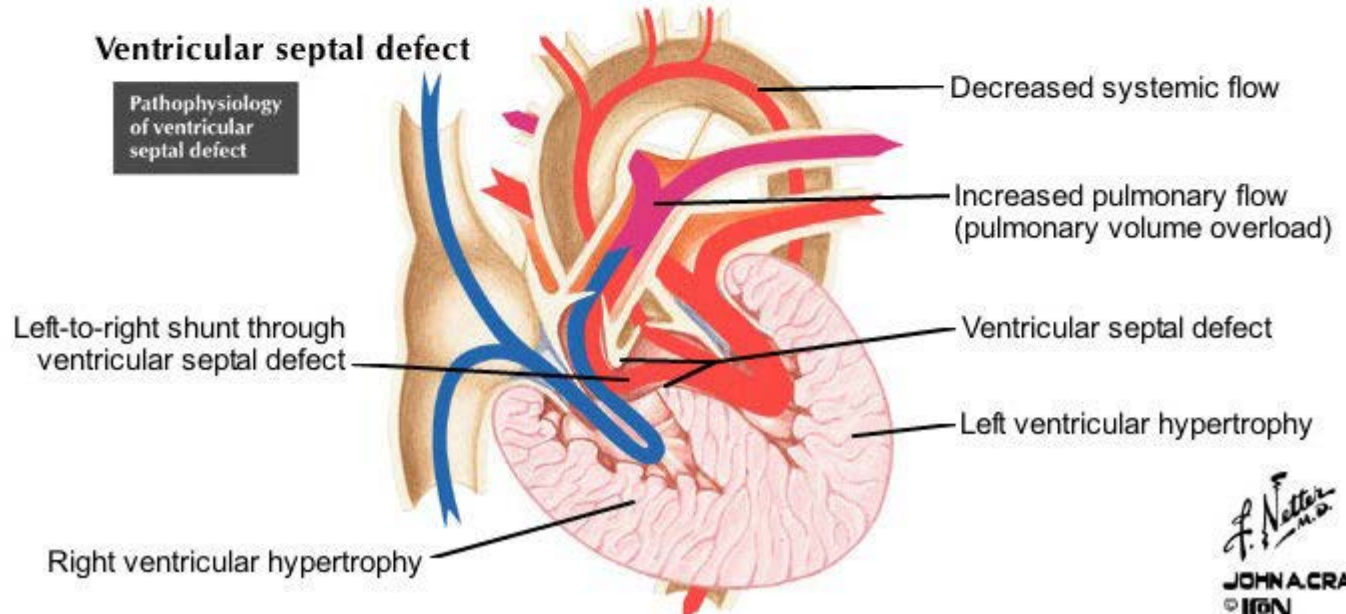


Subpulmonic defect

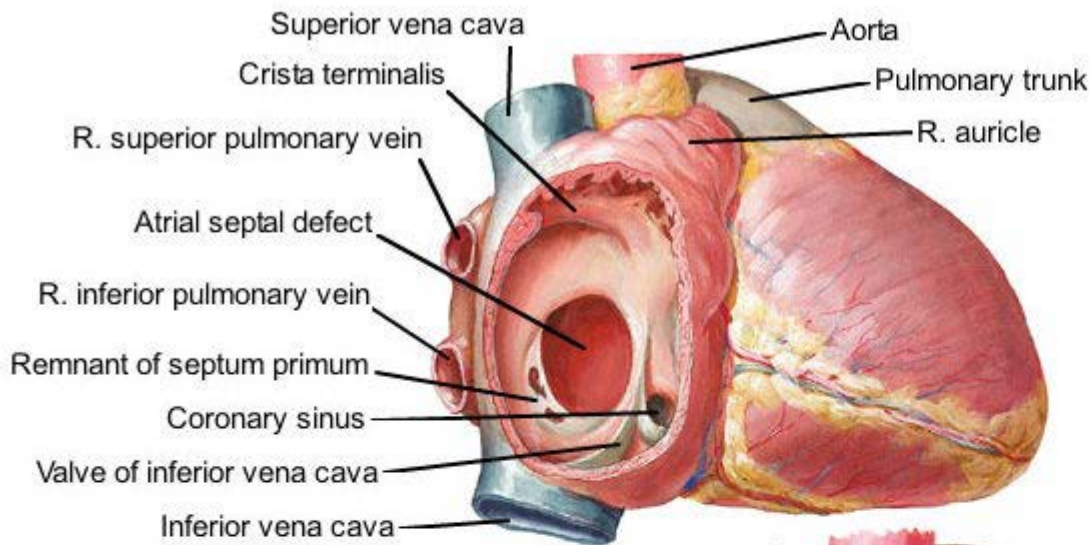


Ventricular septal defect

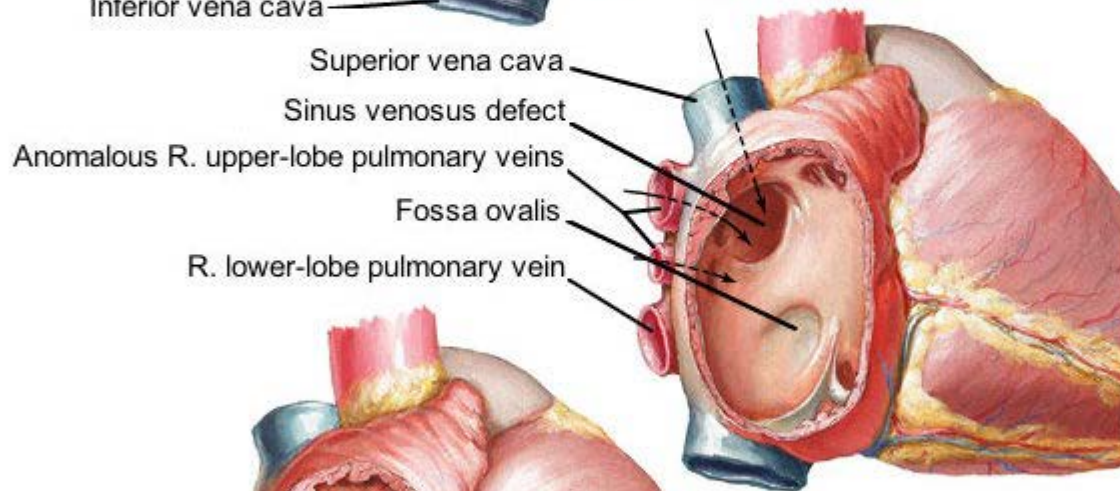
Pathophysiology  
of ventricular  
septal defect



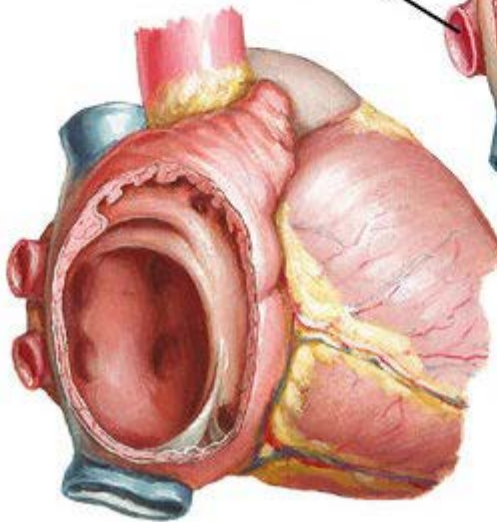
# Atrial Septal Defects



**Foramen secundum defect**



**Sinus venosus defect**

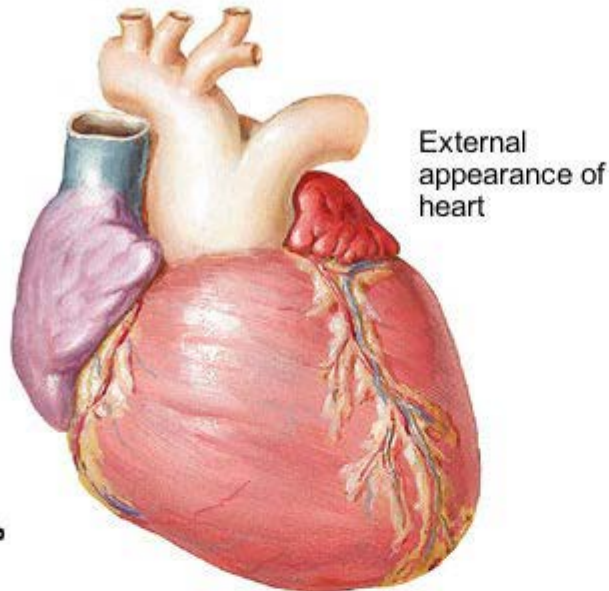


**Common atrium**

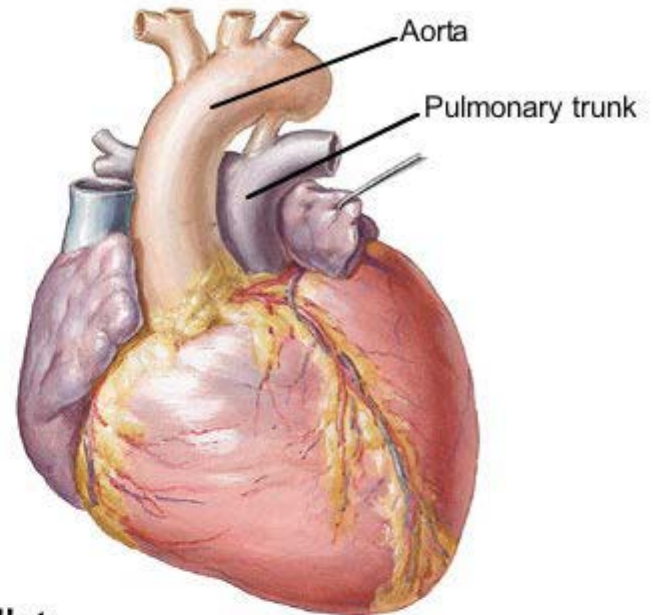


# Spiral Septum Defects

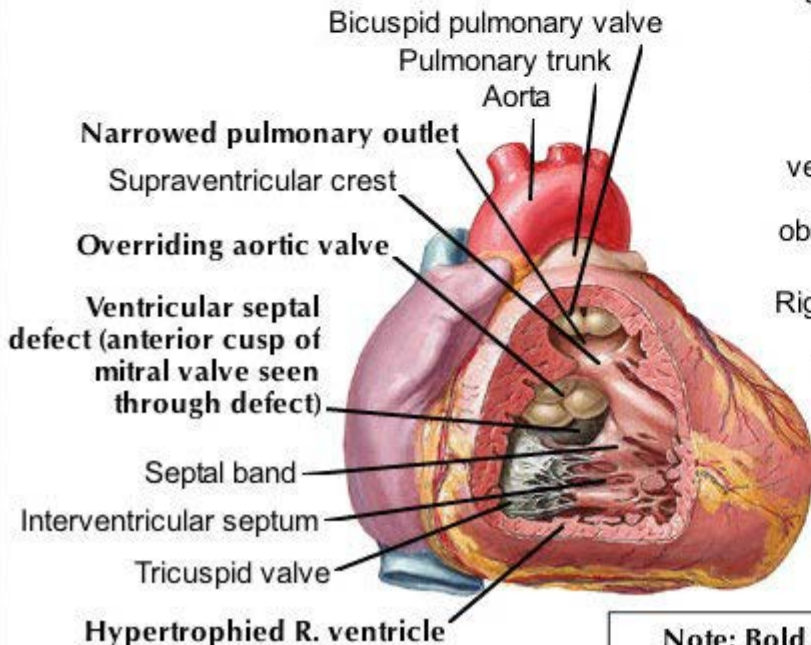
Persistent truncus arteriosus



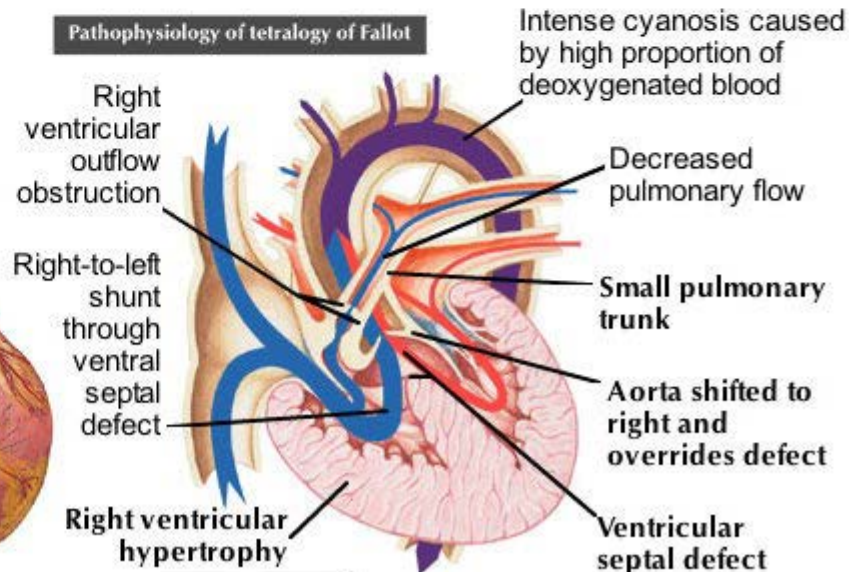
Transposition of great vessels



Tetralogy of Fallot

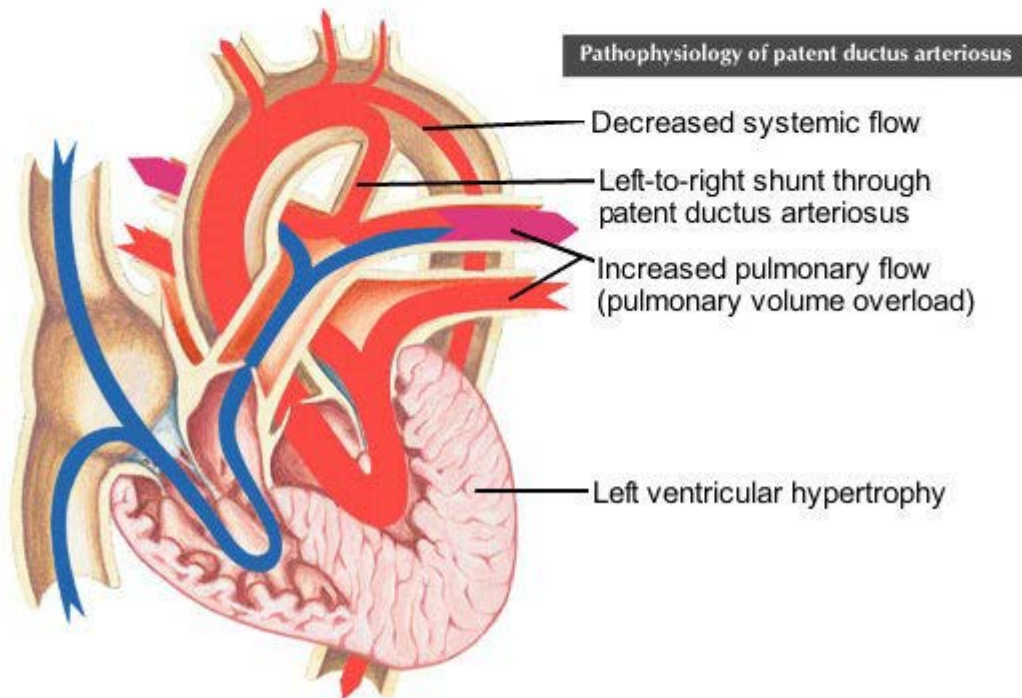
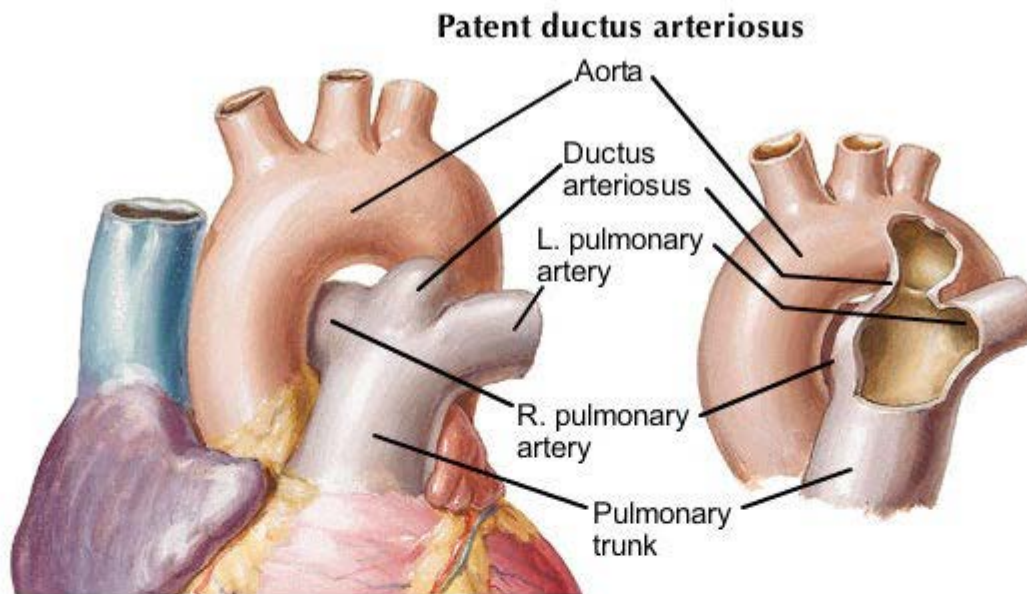


Pathophysiology of tetralogy of Fallot



Note: Bold labels indicate the four primary defects

# Patent Ductus Arteriosus





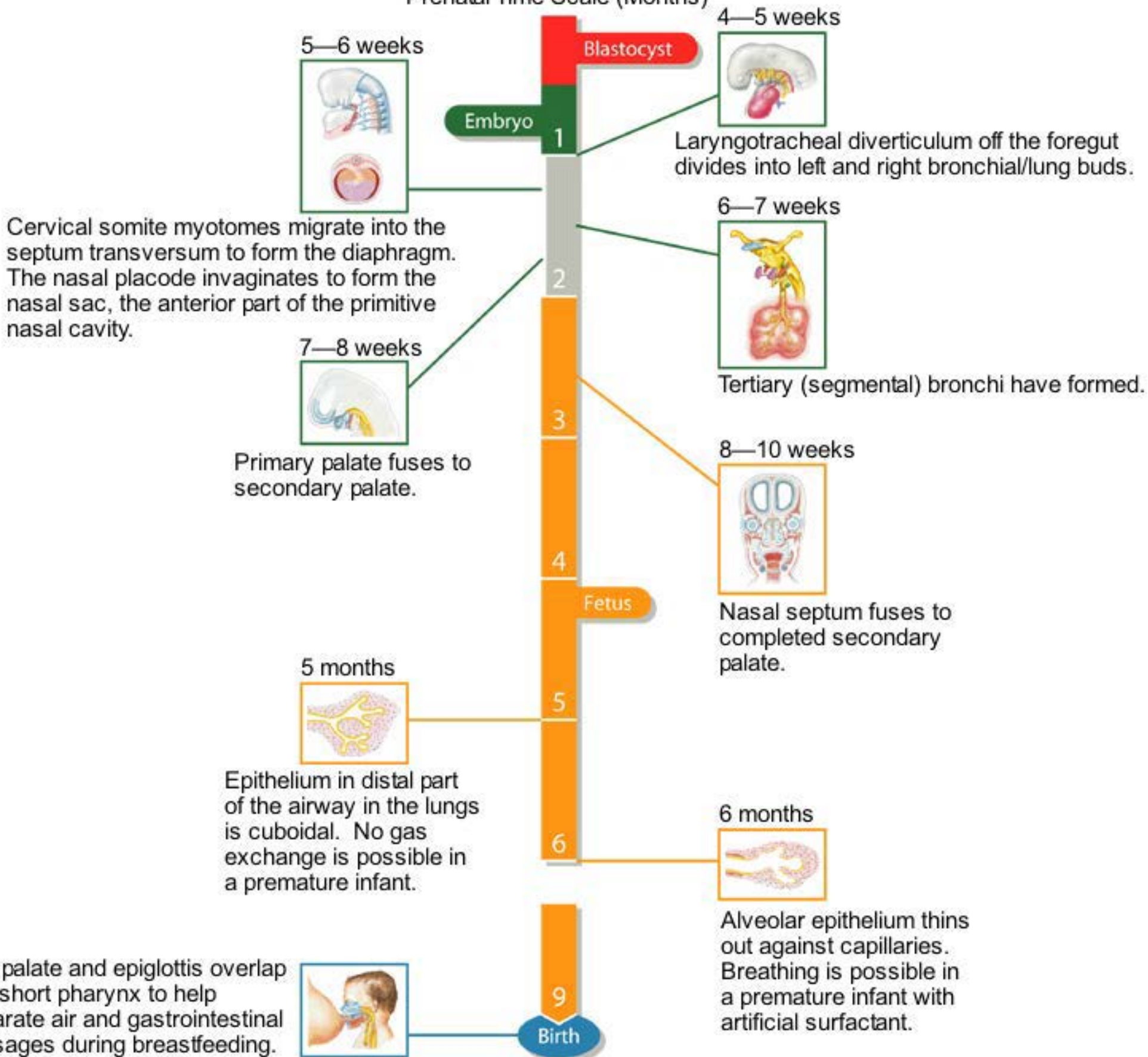
# Chart 4.1 Embryonic Blood Vessel Derivatives

CHART 4.1 EMBRYONIC BLOOD VESSEL DERIVATIVES

Embryonic Vessels	Major Derivatives
Aortic arch artery 1	Part of maxillary arteries
Aortic arch artery 3	Common and internal carotid arteries
Aortic arch artery 4	Right subclavian artery; part of aortic arch
Aortic arch artery 6	Ductus arteriosus; proximal pulmonary arteries
Intersegmental arteries	Intercostal arteries Lumbar arteries Common iliac arteries Parts of vertebral, subclavian, and lateral sacral arteries
Umbilical arteries	Medial umbilical ligaments on the internal aspect of the abdominal wall
Umbilical vein	Round ligament of the liver (ligamentum teres)
Vitelline arteries	Celiac trunk Superior mesenteric artery Inferior mesenteric artery
Vitelline veins	Hepatic portal system Hepatic veins Intrahepatic segment of the inferior vena cava
Anterior cardinal veins	Superior vena cava Brachiocephalic (innominate) veins Internal jugular veins
Subcardinal veins (and anastomoses between the systems)	Lower inferior vena cava Renal and suprarenal veins Gonadal veins
Supracardinal veins	Azygous system of veins Segment of the inferior vena cava between the kidneys and liver

# THE RESPIRATORY SYSTEM TIMELINE

Prenatal Time Scale (Months)

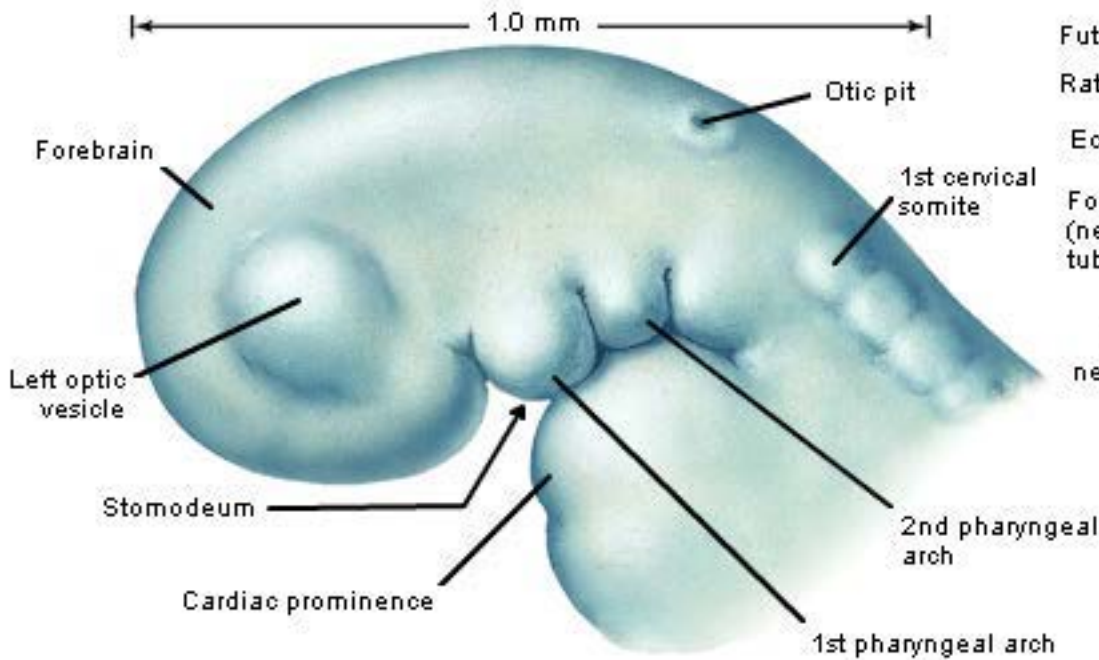




# Early Primordia

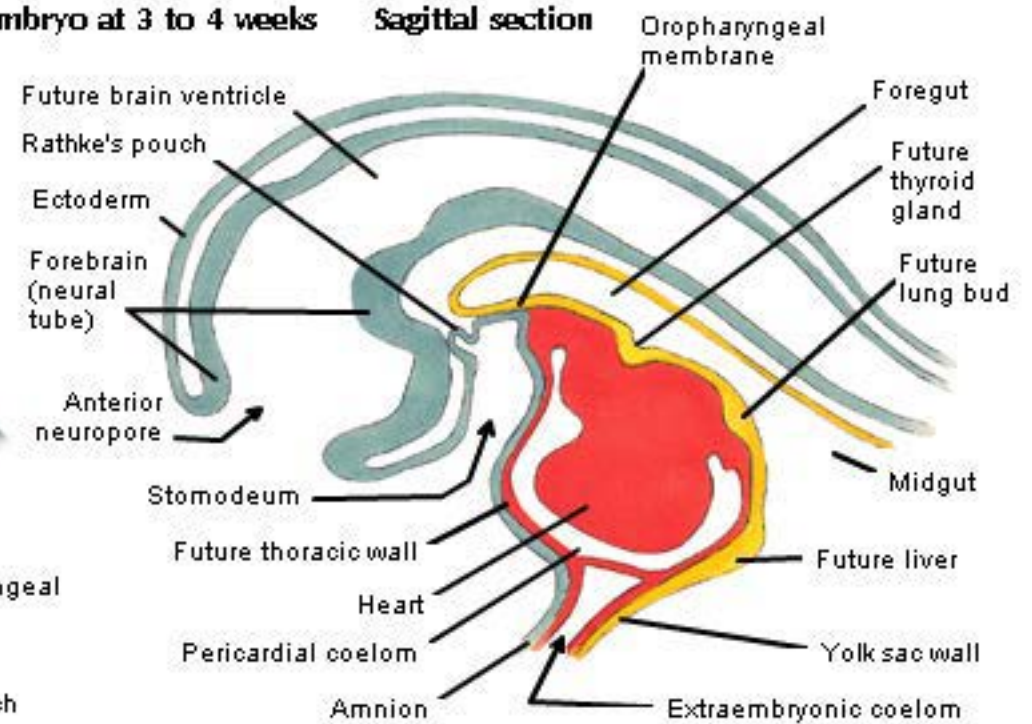
Embryo at 3 to 4 weeks

Lateral View

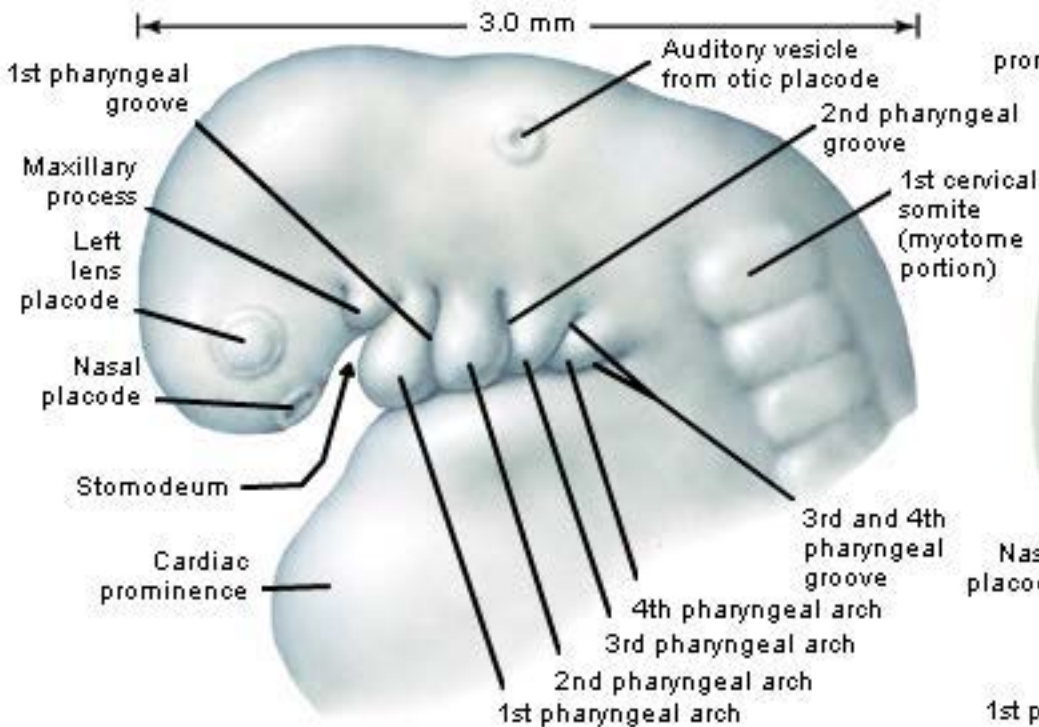


Embryo at 3 to 4 weeks

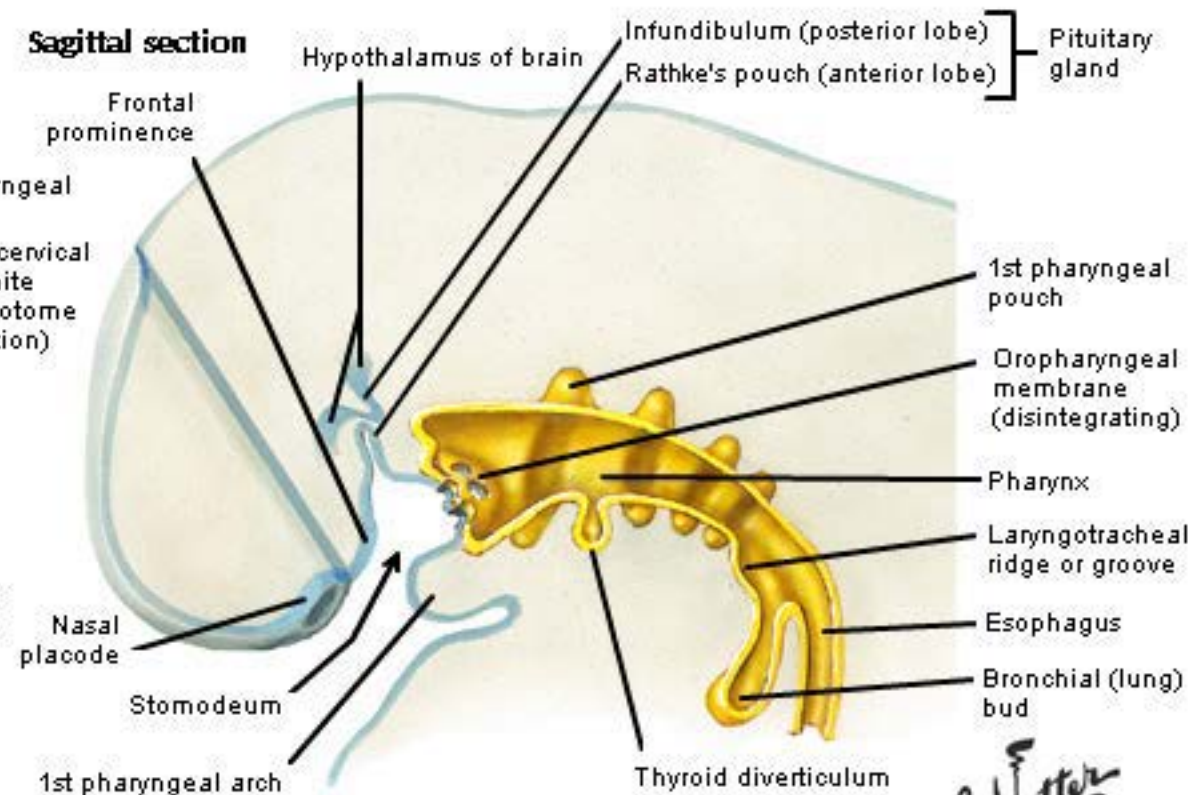
Sagittal section



Lateral view (4 to 5 weeks)



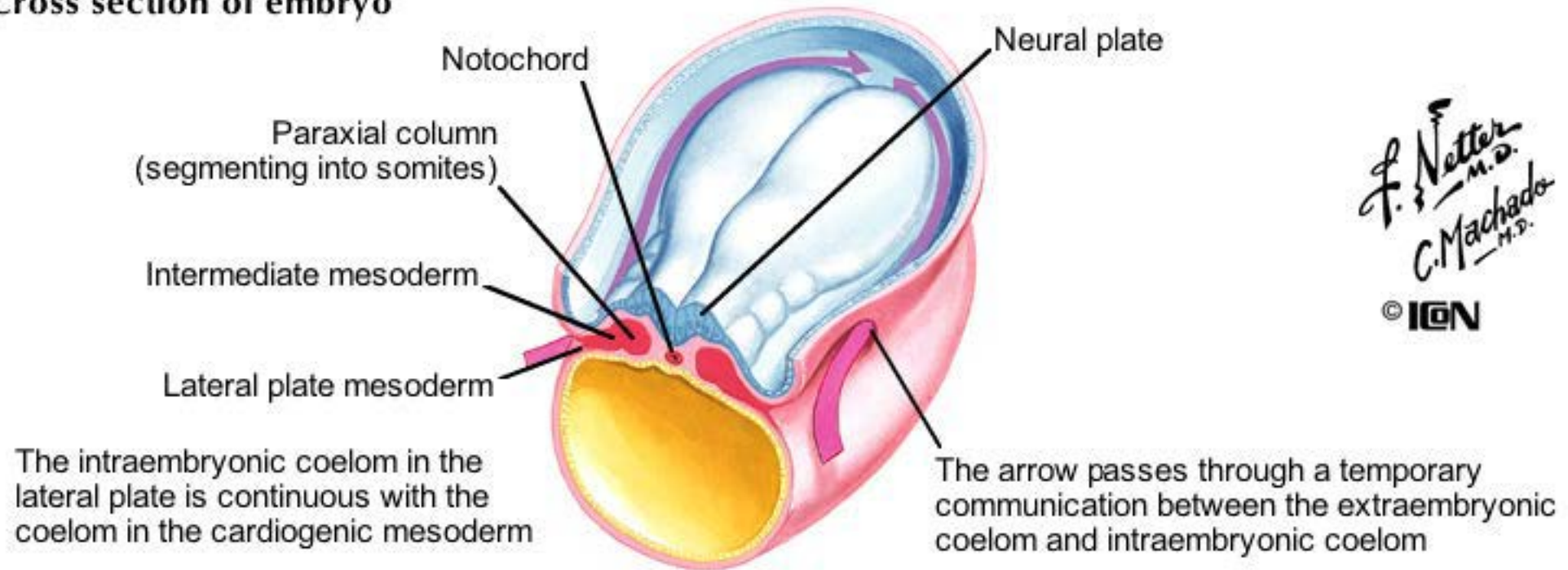
Sagittal section





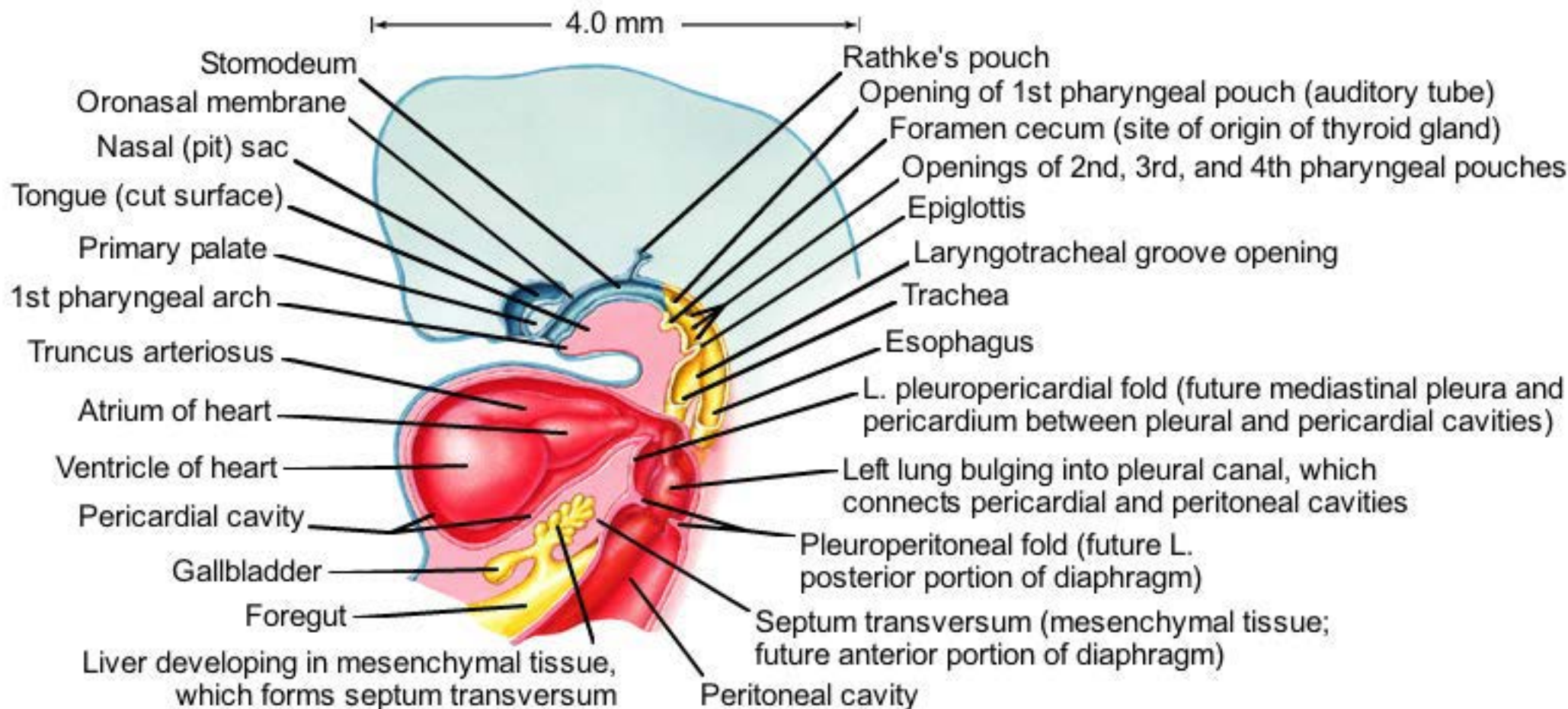
## Formation of the Pleural Cavities

### A. Cross section of embryo



F. Netter  
C. Machado  
© ION

### B. Sagittal section at 5 to 6 weeks

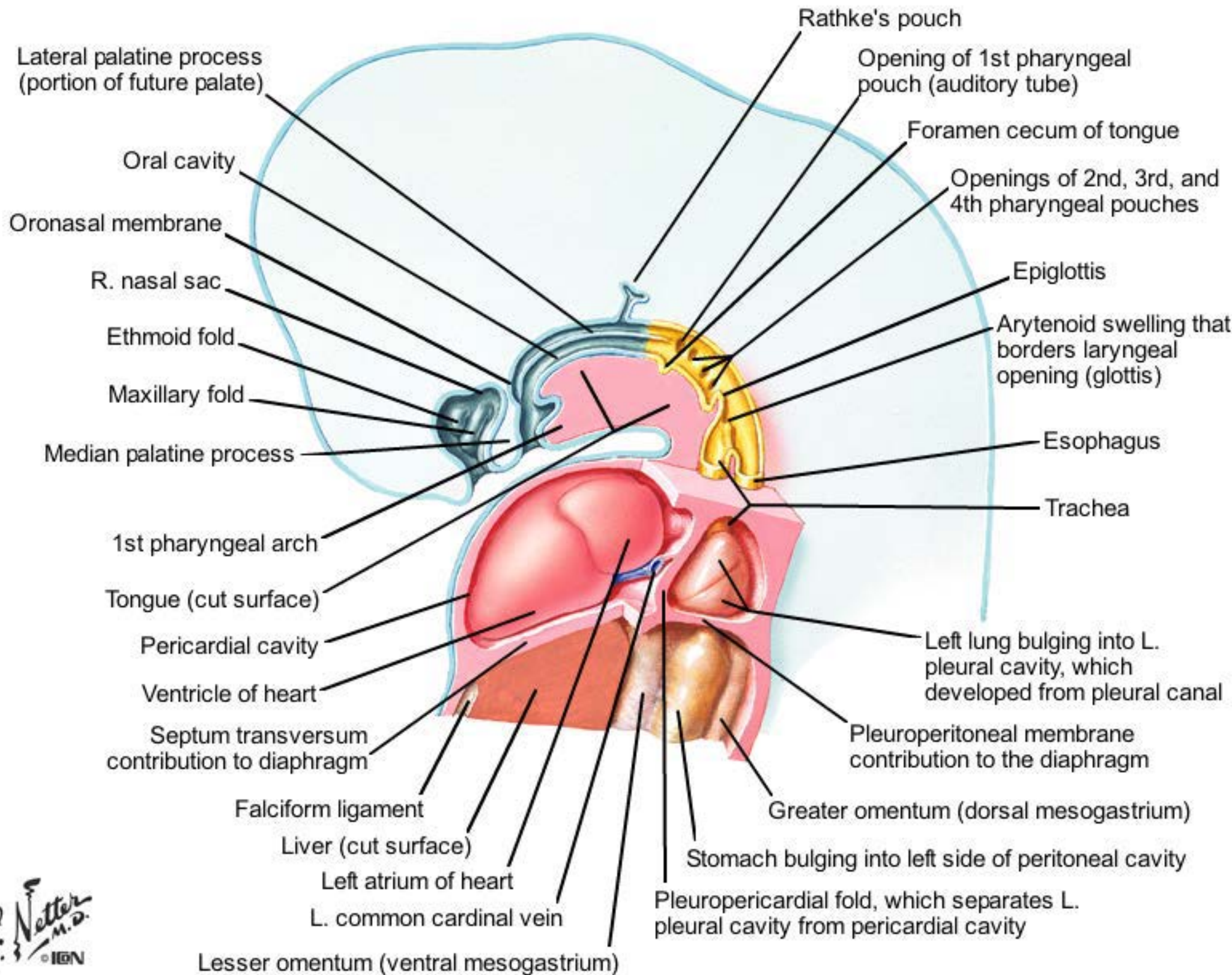




# The Relationship Between Lungs and Pleural Cavities

## Sagittal section at 6 to 7 weeks

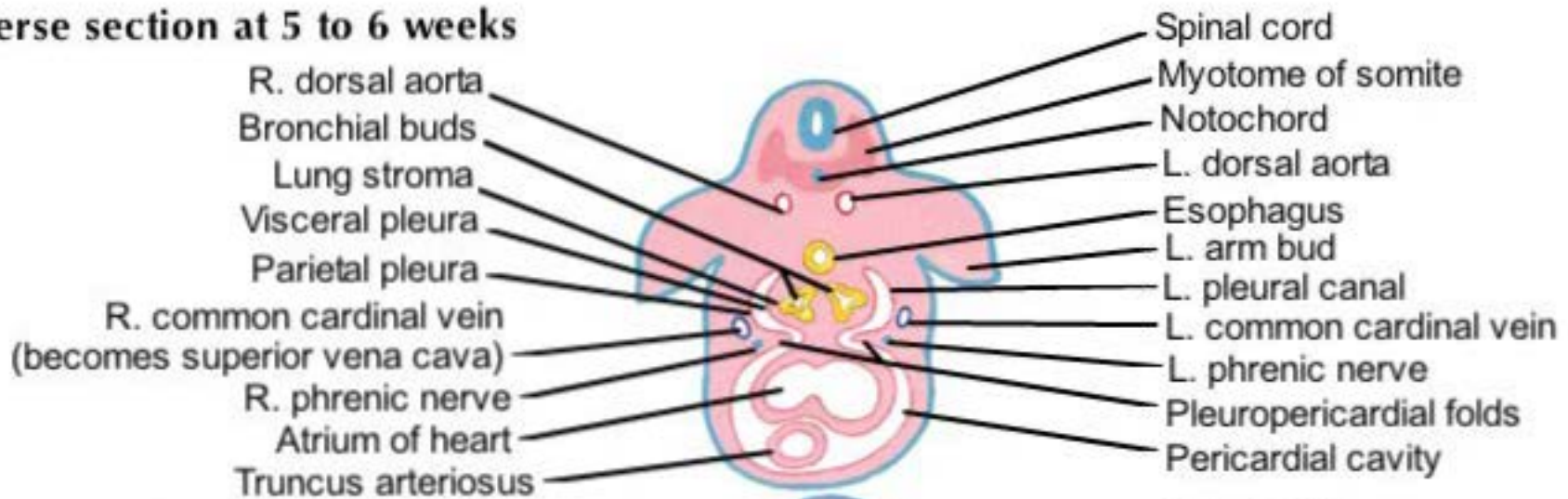
7.0 mm



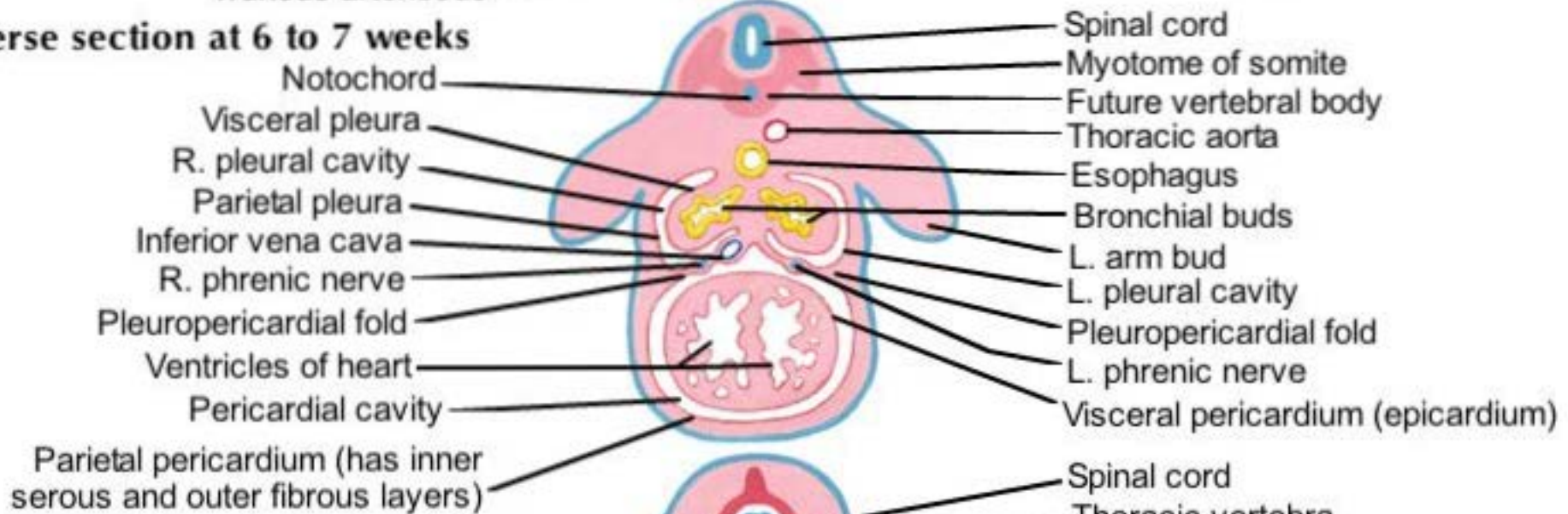


# Visceral and Parietal Pleura

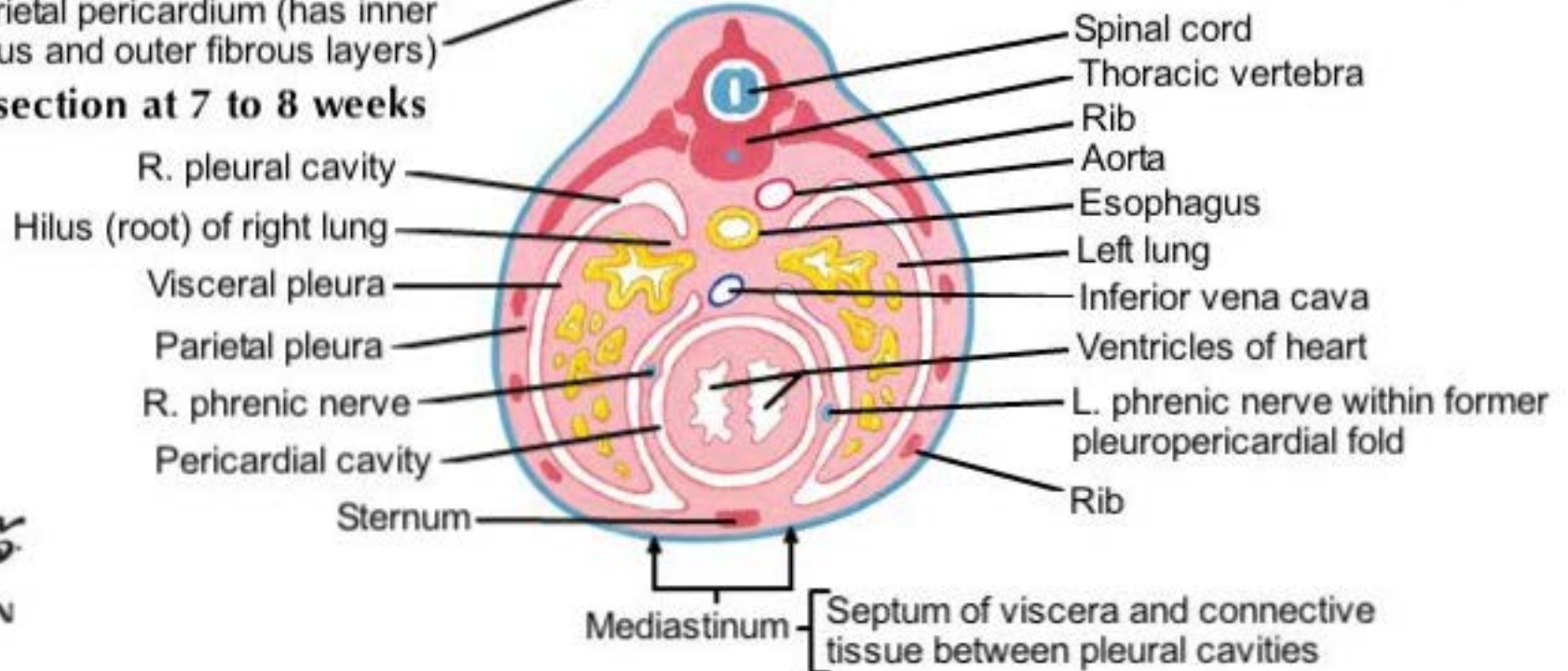
## Transverse section at 5 to 6 weeks



## Transverse section at 6 to 7 weeks



## Transverse section at 7 to 8 weeks

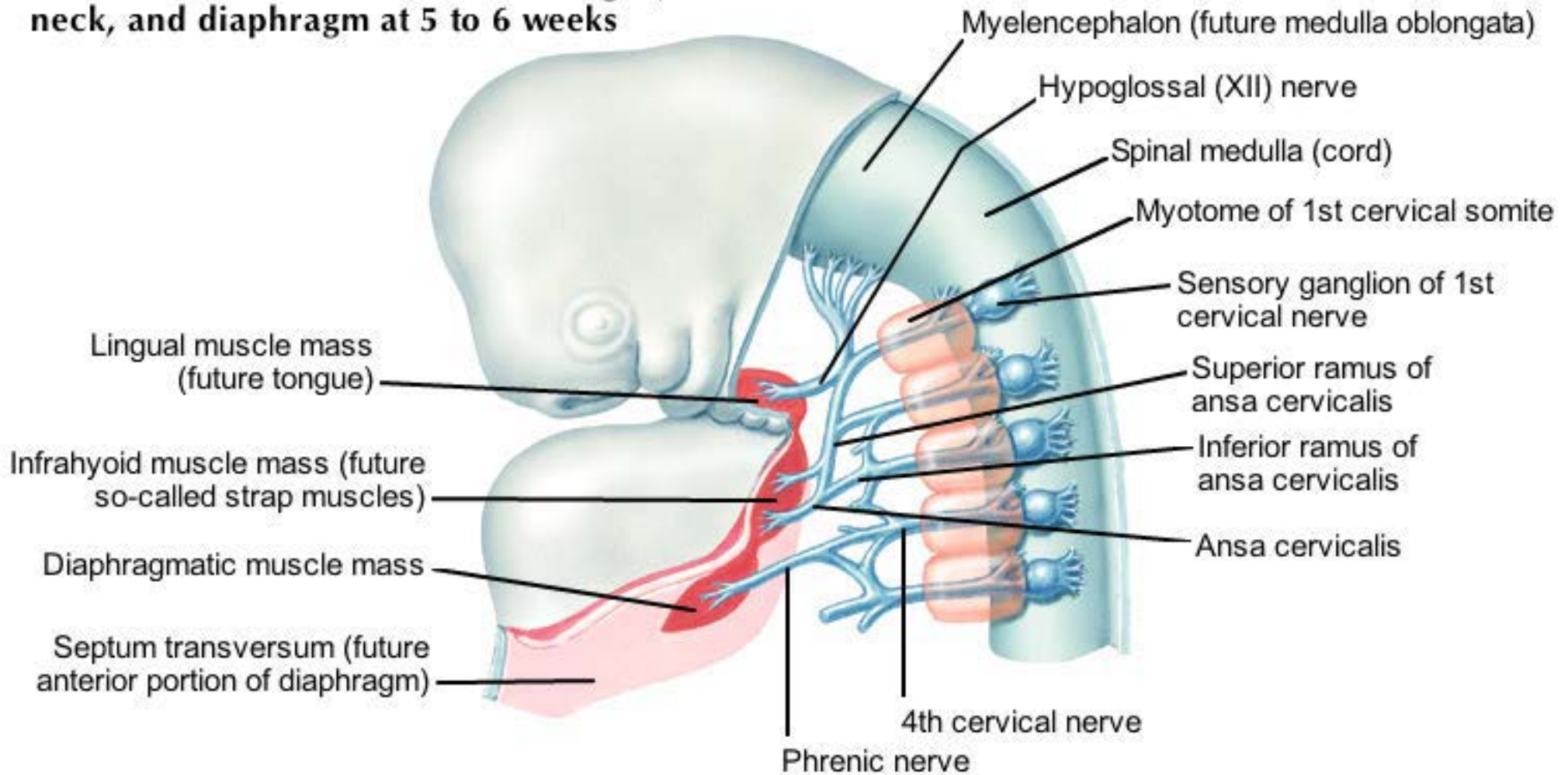




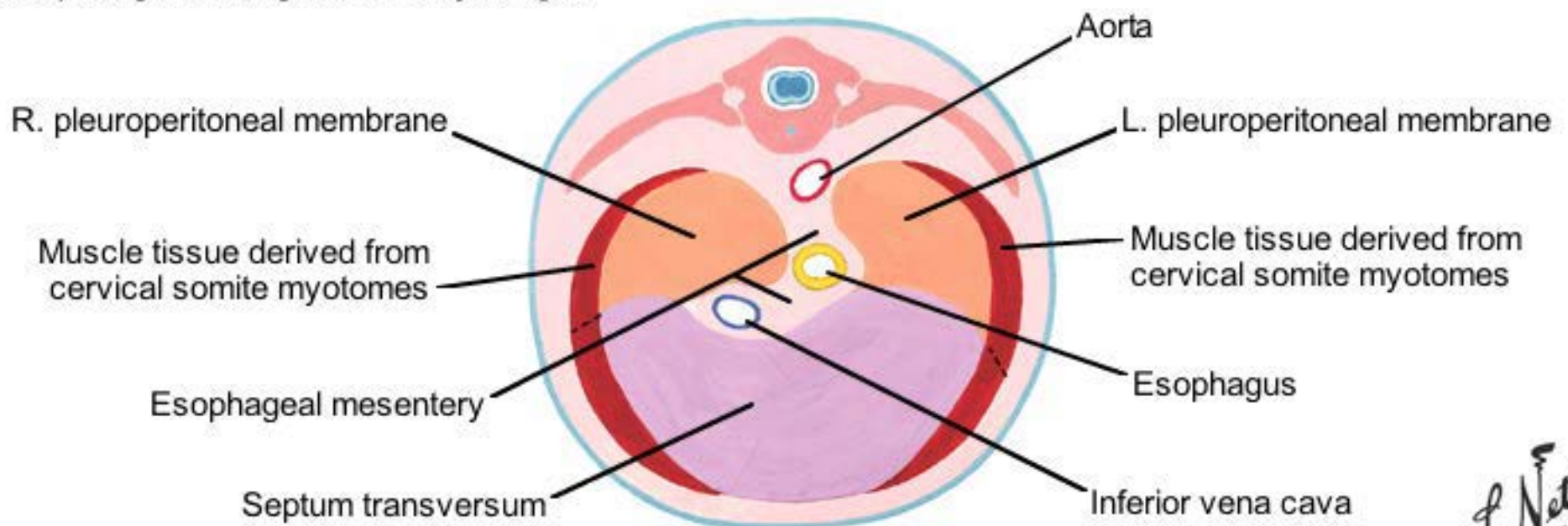
# Development of the Diaphragm

4.0 mm

**Innervation of muscle masses of tongue, neck, and diaphragm at 5 to 6 weeks**

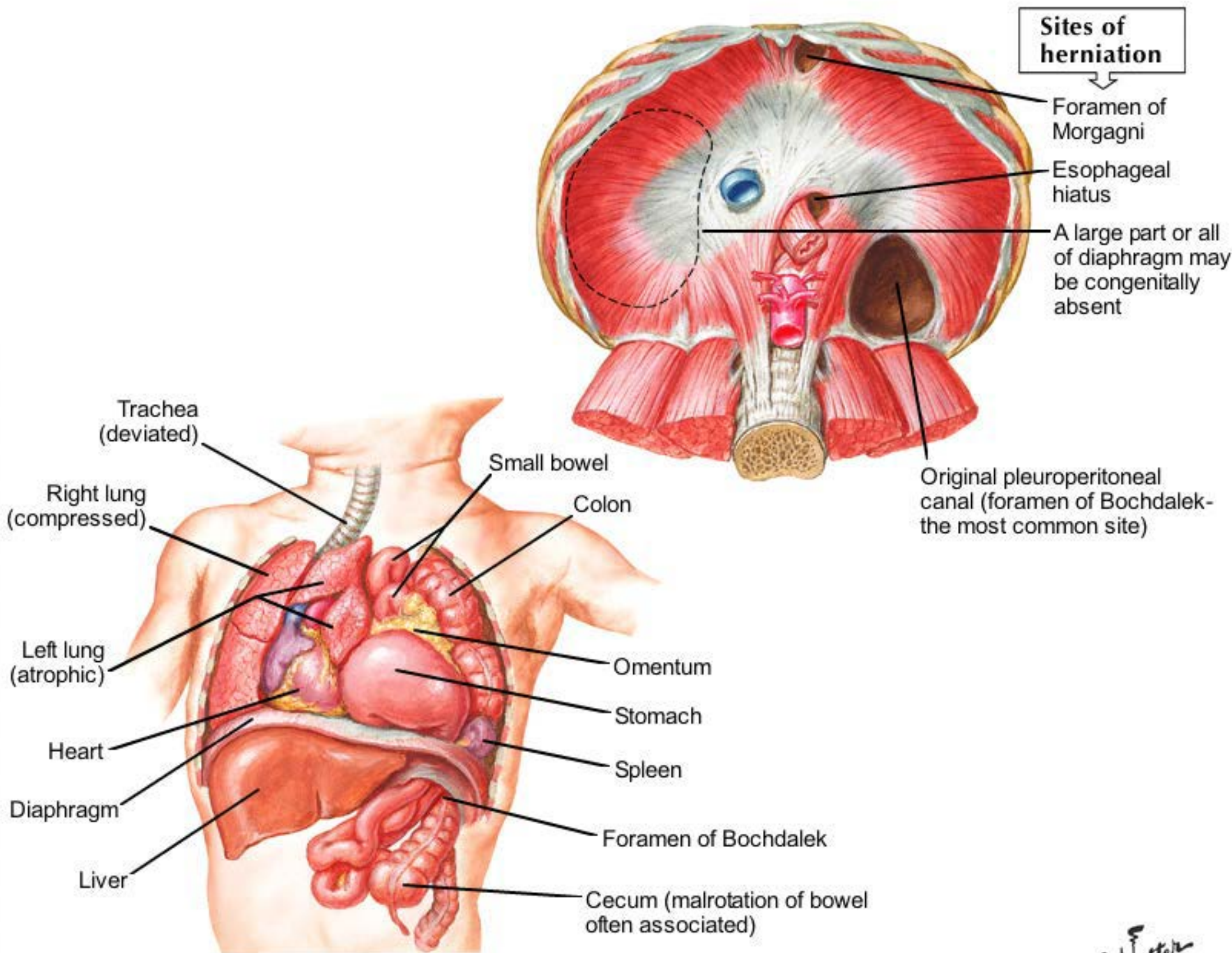


## Embryological origins of diaphragm





# Congenital Diaphragmatic Hernia

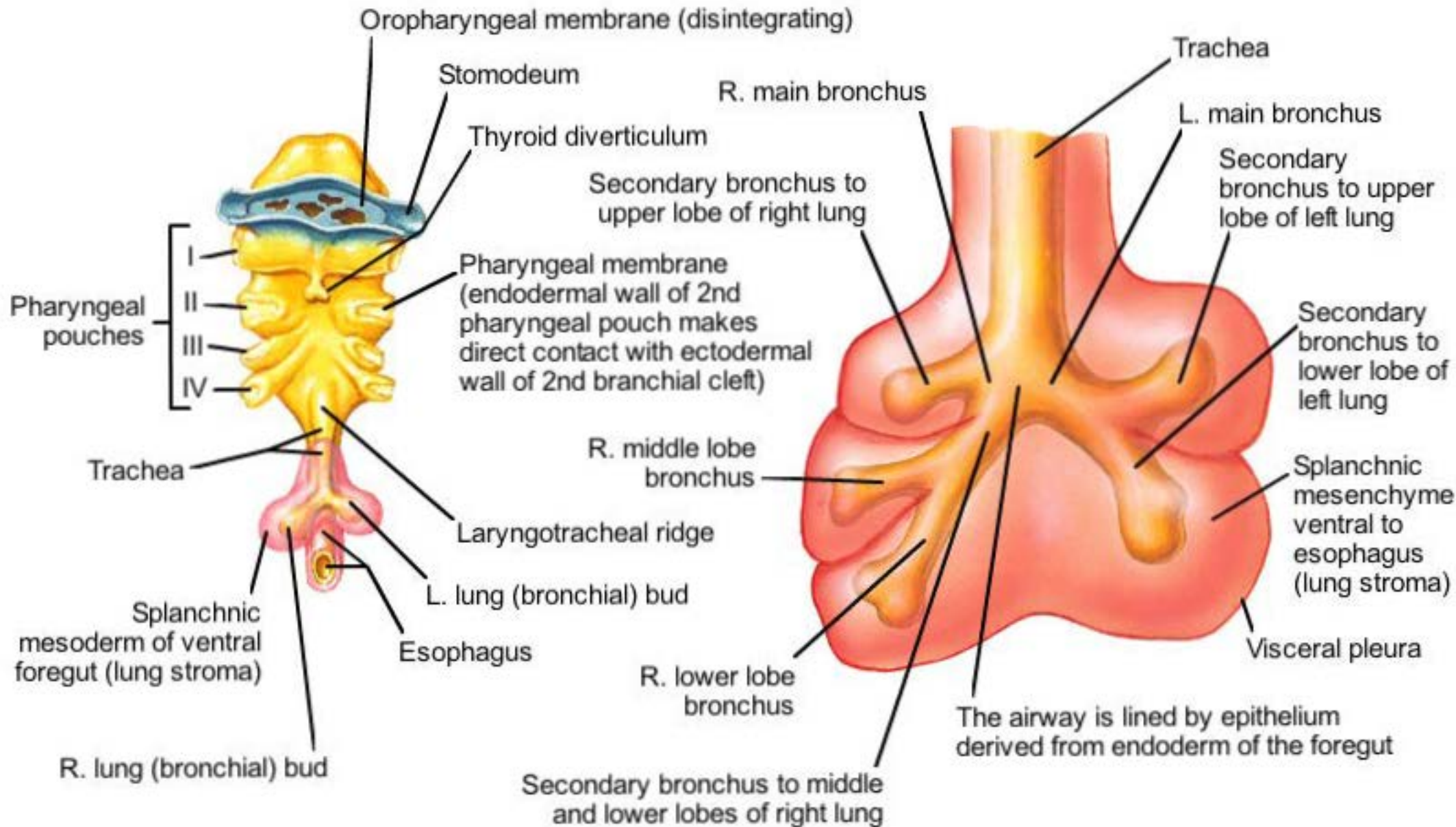




# Airway Branching

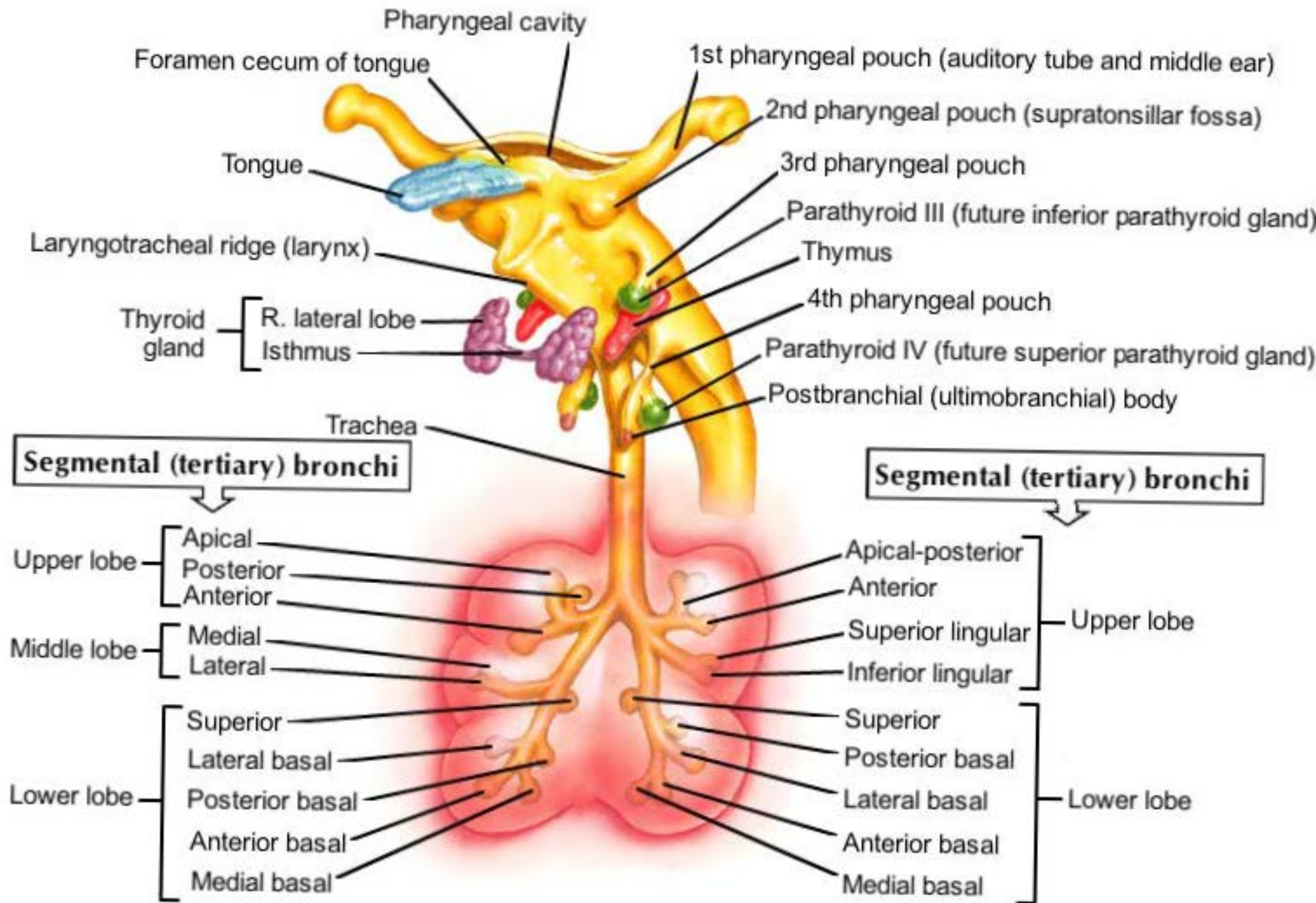
Upper foregut at 4 to 5 weeks (ventral view)

Bronchi and lungs at 5 to 6 weeks



# Airway Branching

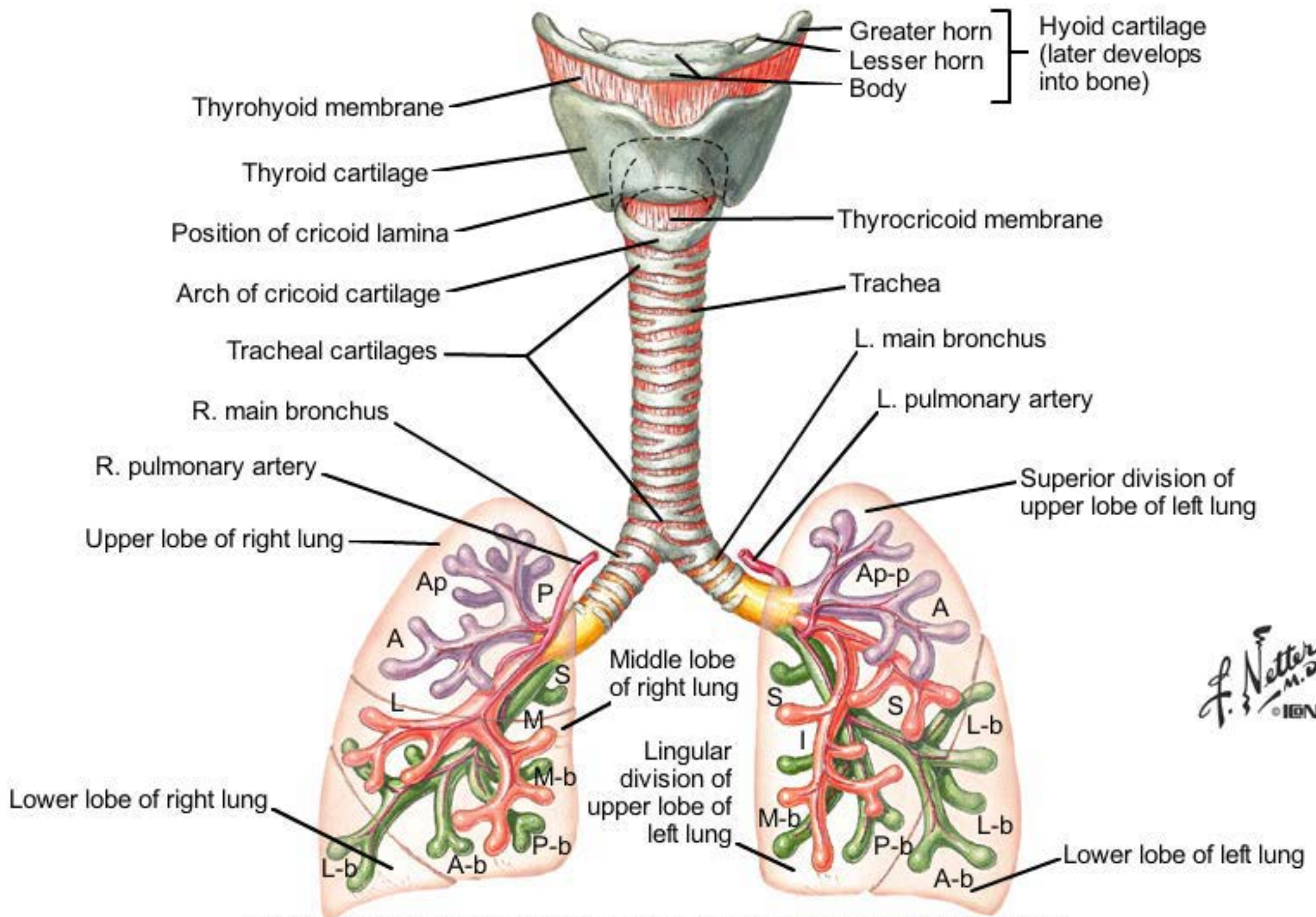
## Respiratory system at 6 to 7 weeks





# Airway Branching

## Larynx, Tracheobronchial Tree, and Lungs at 7 to 10 Weeks






*F. Netter M.D.*  
© IGV

### Tertiary branches of bronchi to bronchopulmonary segments

#### Right lung

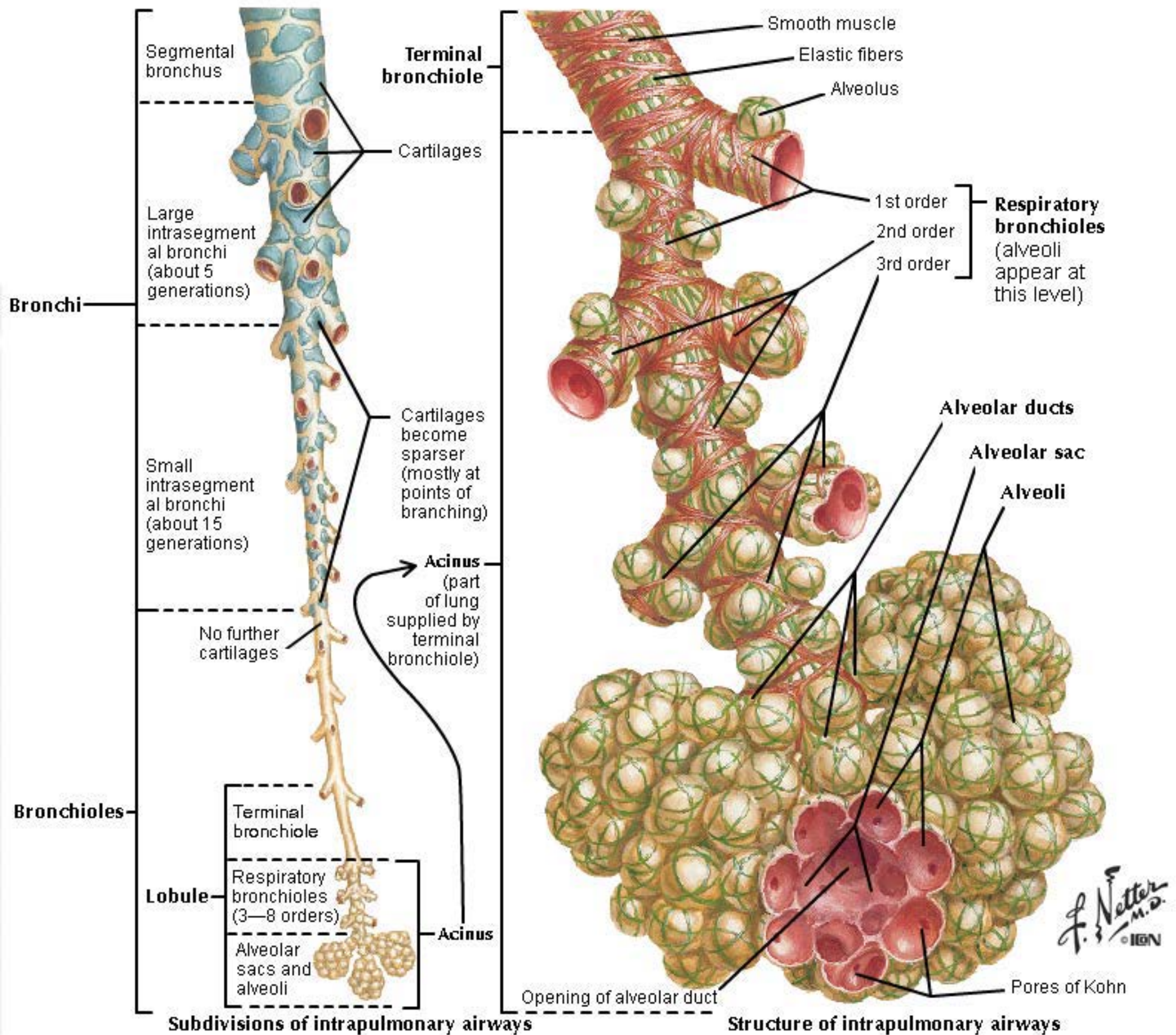
Upper lobe	Apical (Ap), posterior (P), anterior (A)
Middle lobe	Medial (M), lateral (L)
Lower lobe	Superior (S), anterior basal (A-b), posterior basal (P-b), medial basal (M-b), lateral basal (L-b)

#### Left lung

	Upper lobe	Superior division	Apical posterior (Ap-p), Anterior (A)
		Lingular division	Superior (S), inferior (I)
	Lower lobe	Superior (S), anterior basal (A-b), medial basal (M-b), posterior basal (P-b), lateral basal (L-b)	



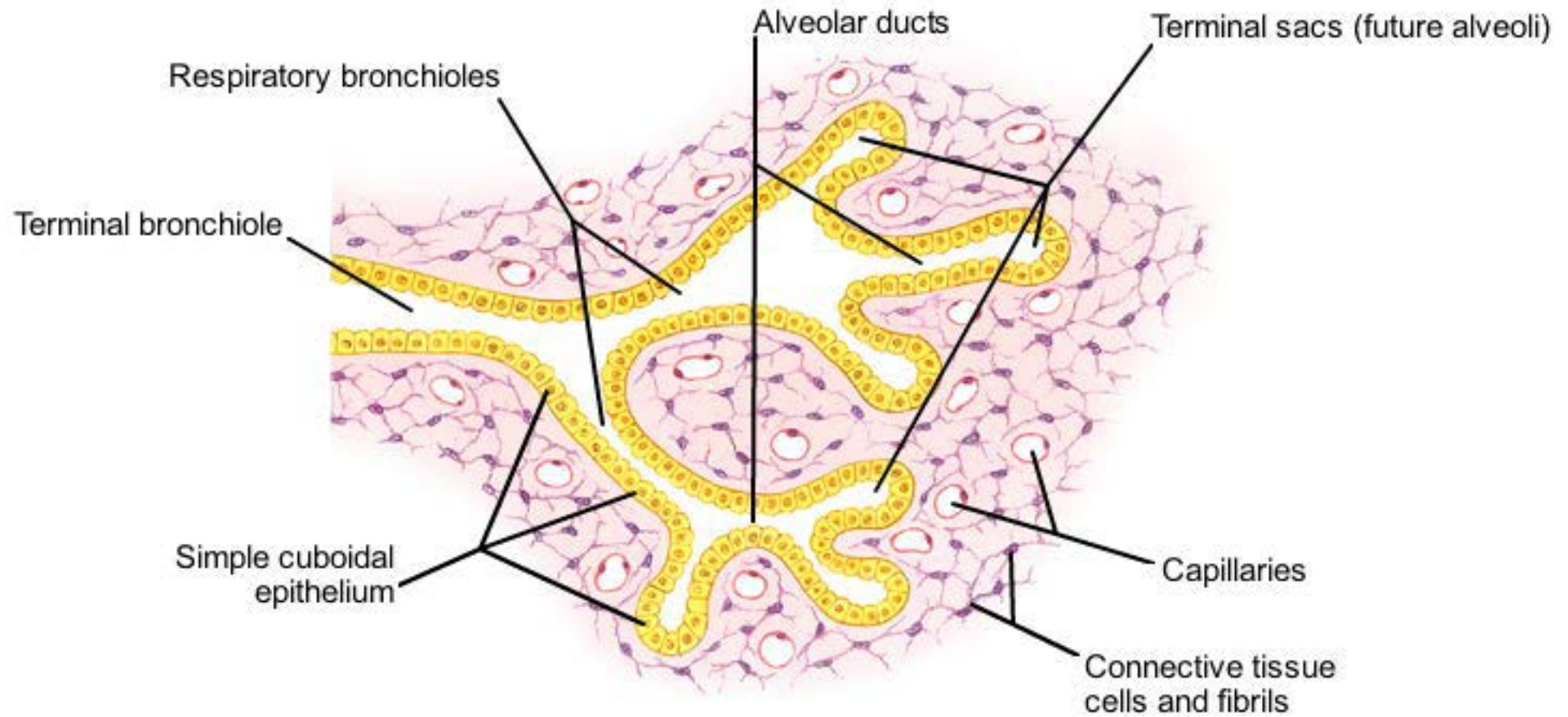
# Airway Branching



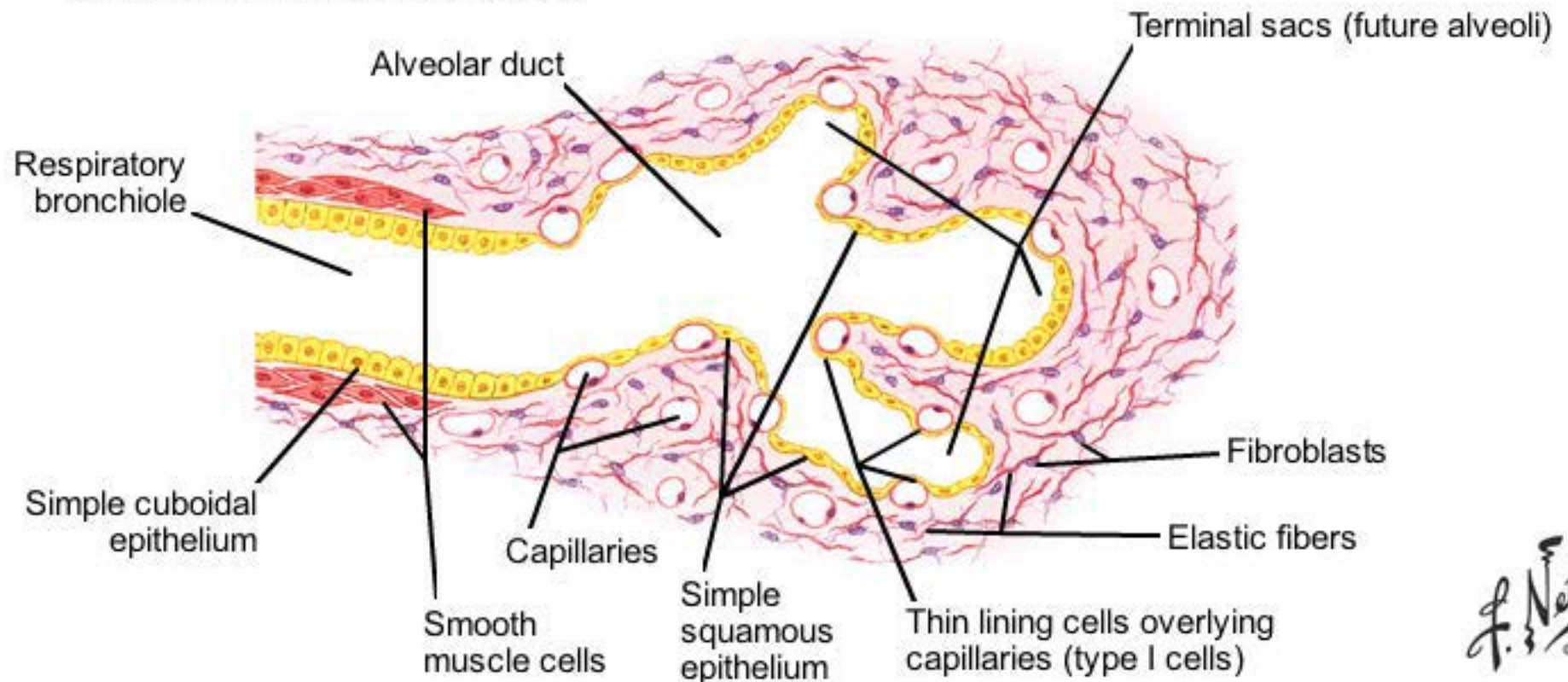


# Bronchial Epithelium Maturation

## Terminal air tube at 20 weeks



## Terminal air tube at 24 weeks



# Congenital Anomalies of the Lower Airway

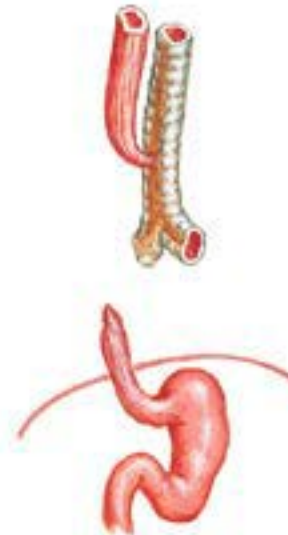
## A. Tracheoesophageal fistula

Most common form (90% to 95%) of tracheoesophageal fistula. Upper segment of esophagus ending in blind pouch; lower segment originating from trachea just above bifurcation. The two segments may be connected by a solid cord



## B. Variations of tracheoesophageal fistula and rare anomalies of trachea

Upper segment of esophagus ending in trachea; lower segment of variable length



C. Double fistula



D. Fistula without esophageal atresia



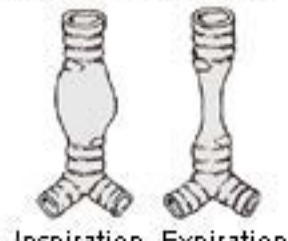
E. Esophageal atresia without fistula



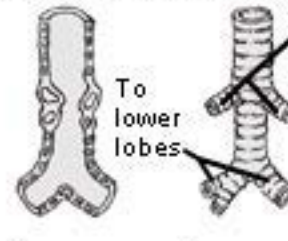
F. Aplasia of trachea (lethal)



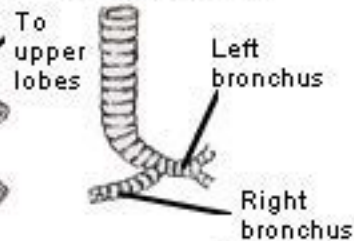
G. Stricture of trachea



H. Absence of cartilage



I. Deformity of cartilage

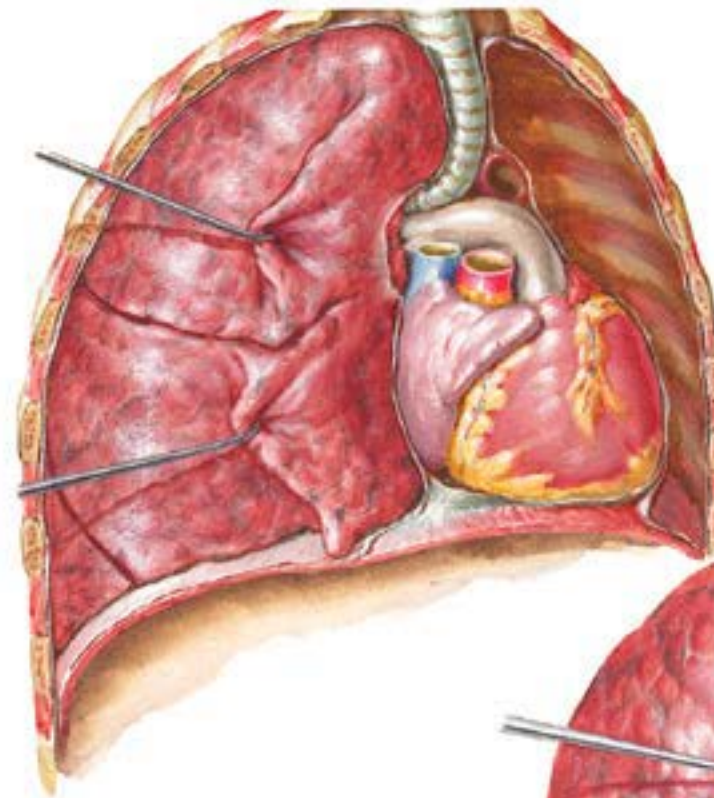


J. Abnormalities of bifurcation

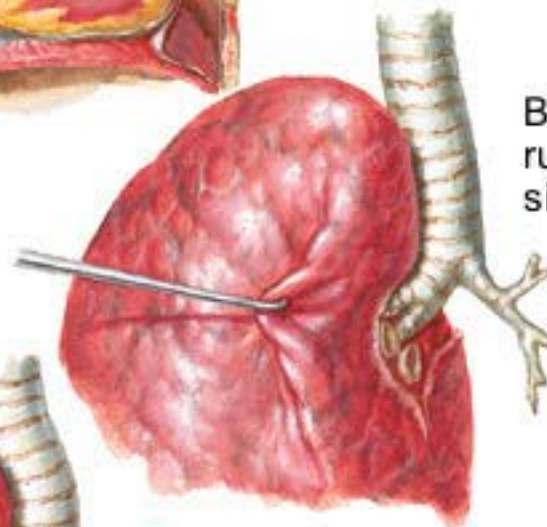


# Airway Branching Anomalies

## Pulmonary agenesis, aplasia, and hypoplasia

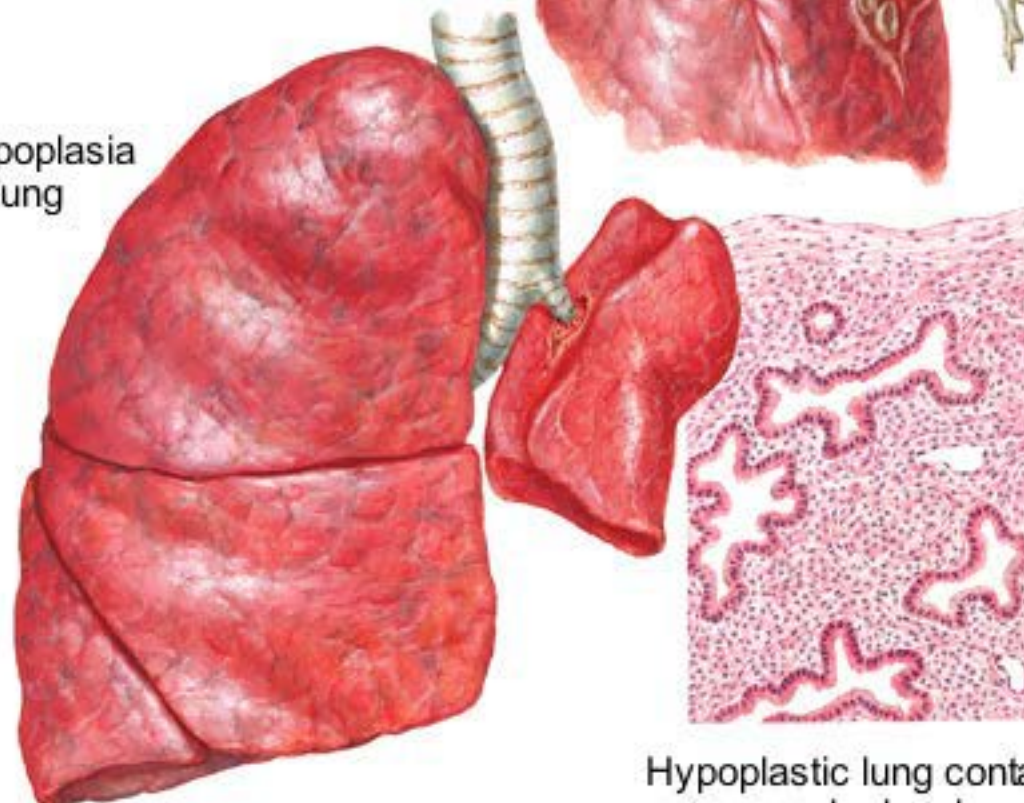


A. Complete unilateral agenesis. Left lung and bronchial tree are absent. Right lung is greatly enlarged with resultant shift of mediastinum to left, elevation of left diaphragm, and approximation of ribs on that side



B. Aplasia of left lung. Only rudimentary bronchi on left side, which end blindly

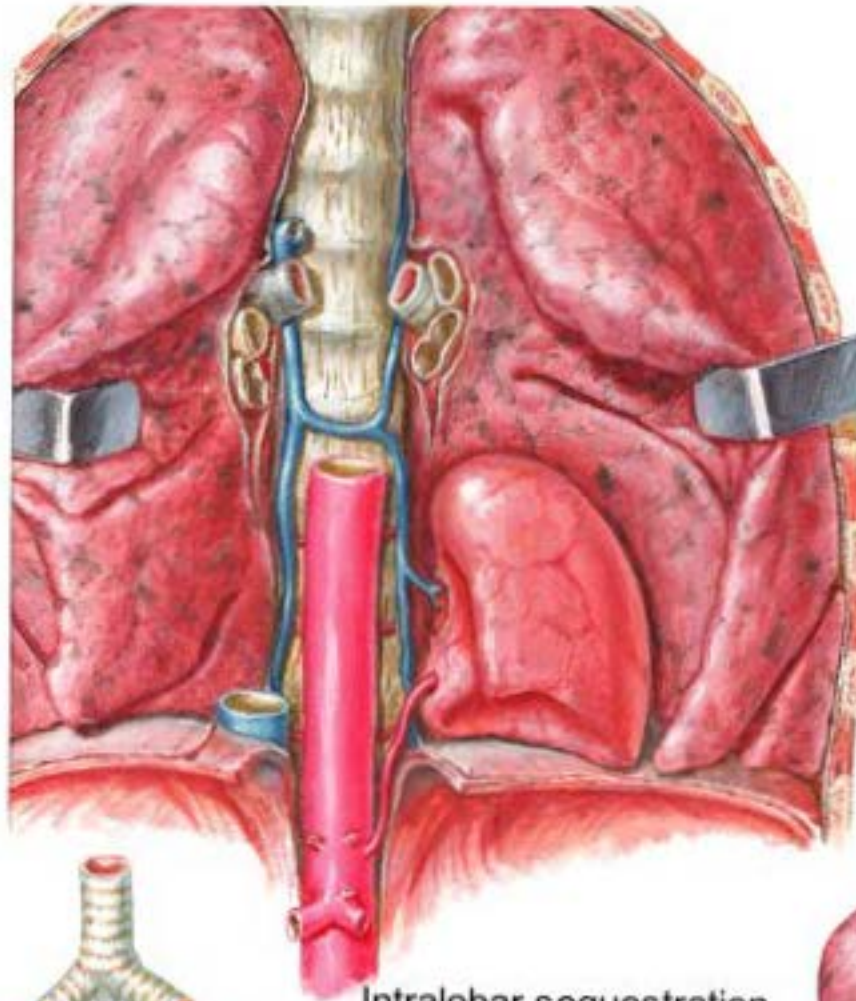
C. Hypoplasia of left lung



Hypoplastic lung contains some poorly developed bronchi but no alveolar tissue

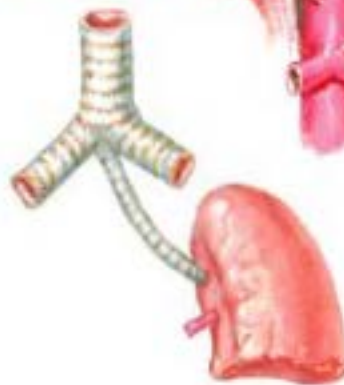


# Bronchopulmonary Sequestration



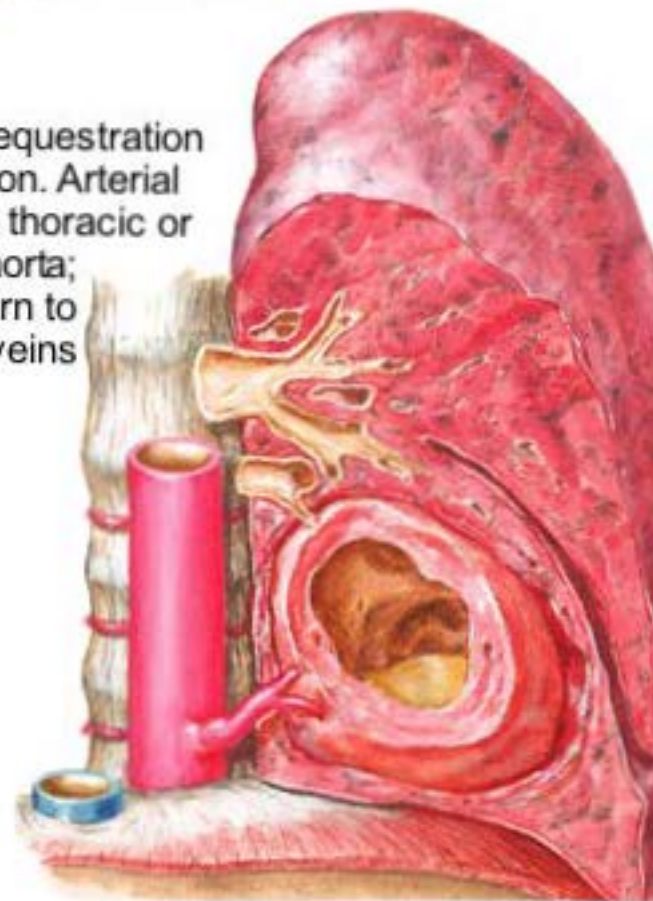
Extralobar sequestered lobe of left lung. Arterial supply from thoracic or abdominal aorta, venous return to hemiazygos vein

Extralobar sequestered lobe supplied by accessory bronchus



Intralobar sequestration with cavitation. Arterial supply from thoracic or abdominal aorta; venous return to pulmonary veins

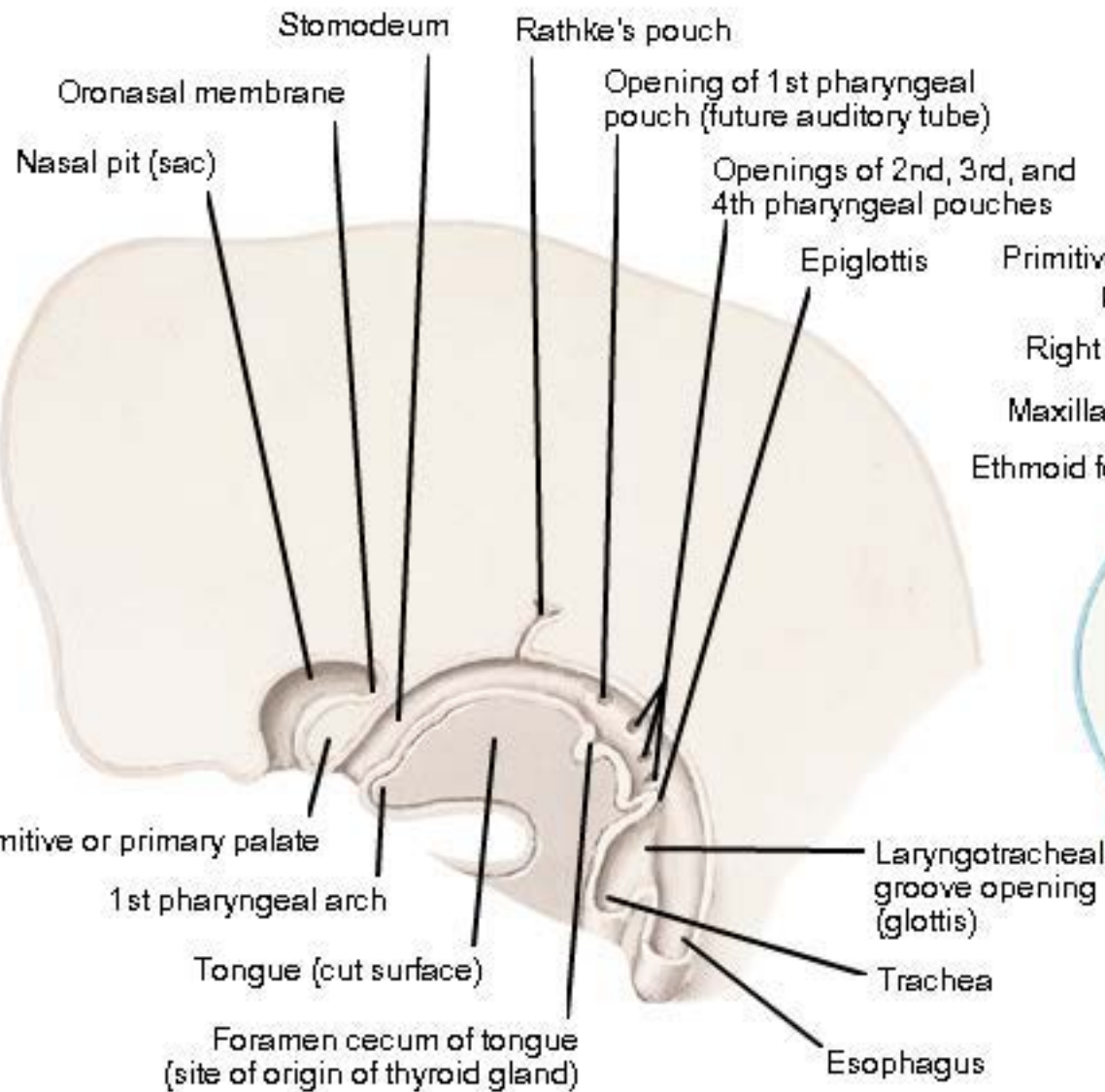
Extralobar sequestered lobe with communication from esophagus (communication with cardia of stomach has also been observed)



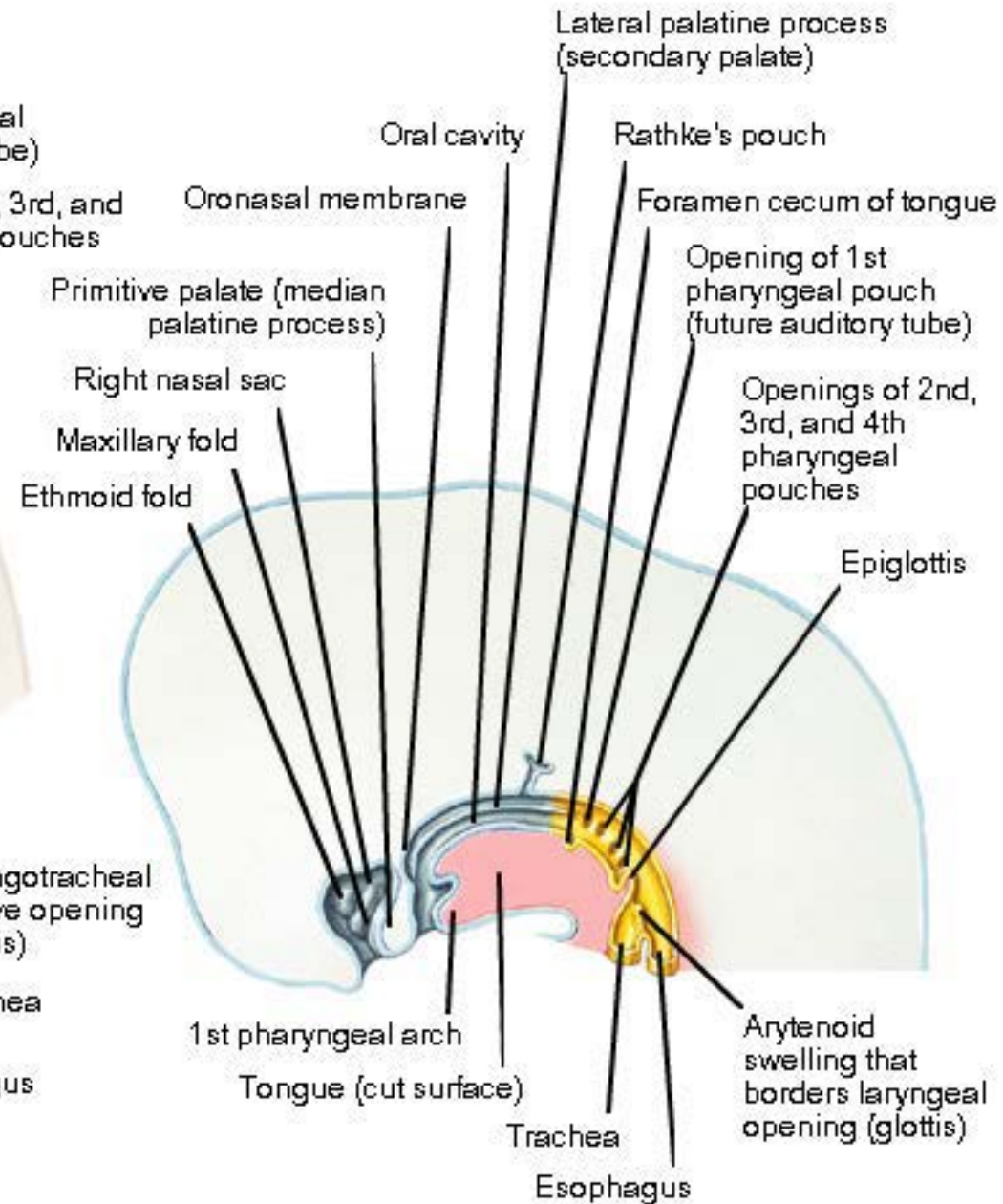


# Palate Formation in the Upper Airway

**Sagittal section (5 to 6 weeks)**



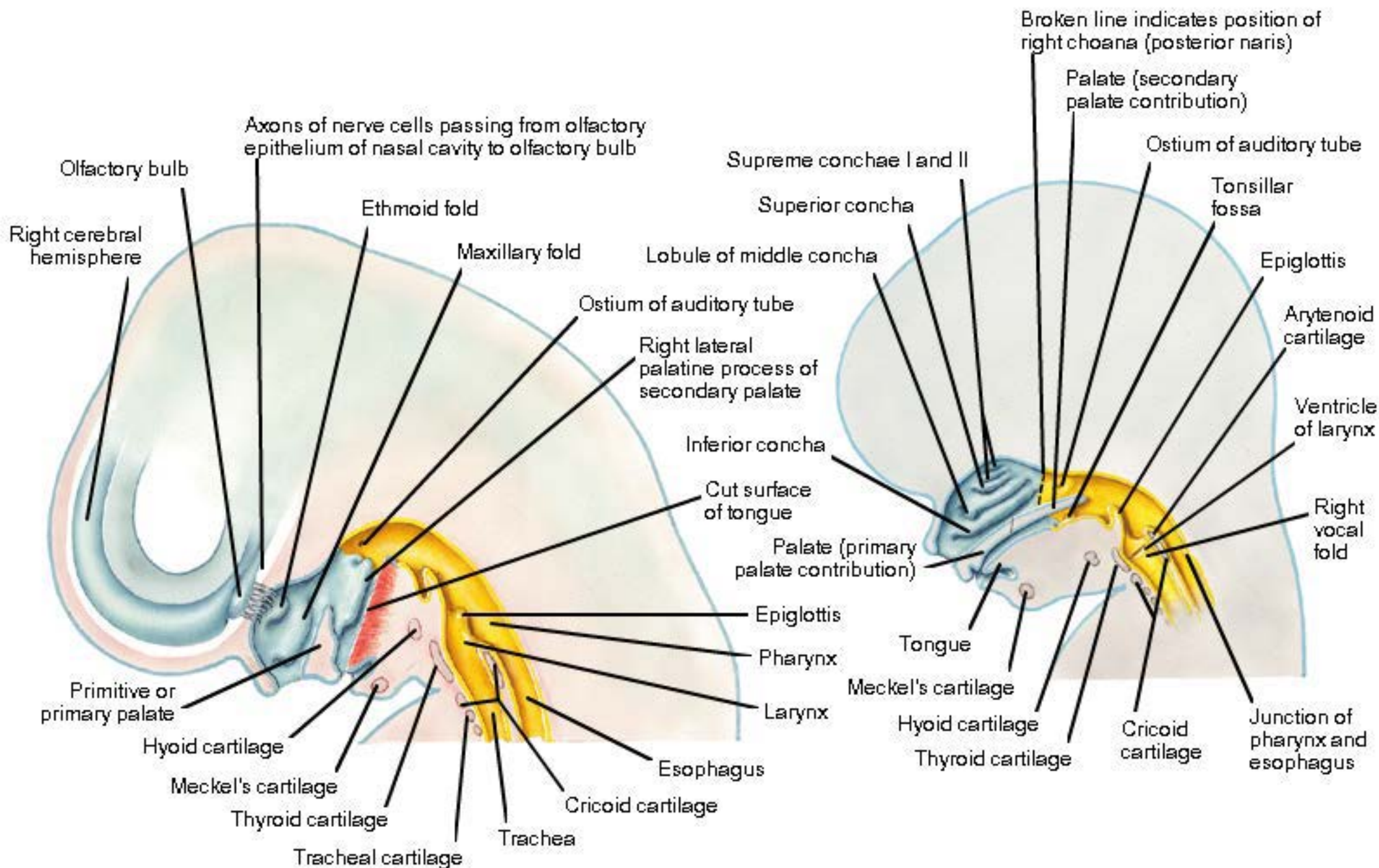
**Sagittal section (6 to 7 weeks)**



# Palate Formation in the Upper Airway

Sagittal section (7 to 8 weeks)

Sagittal section (8 to 10 weeks)

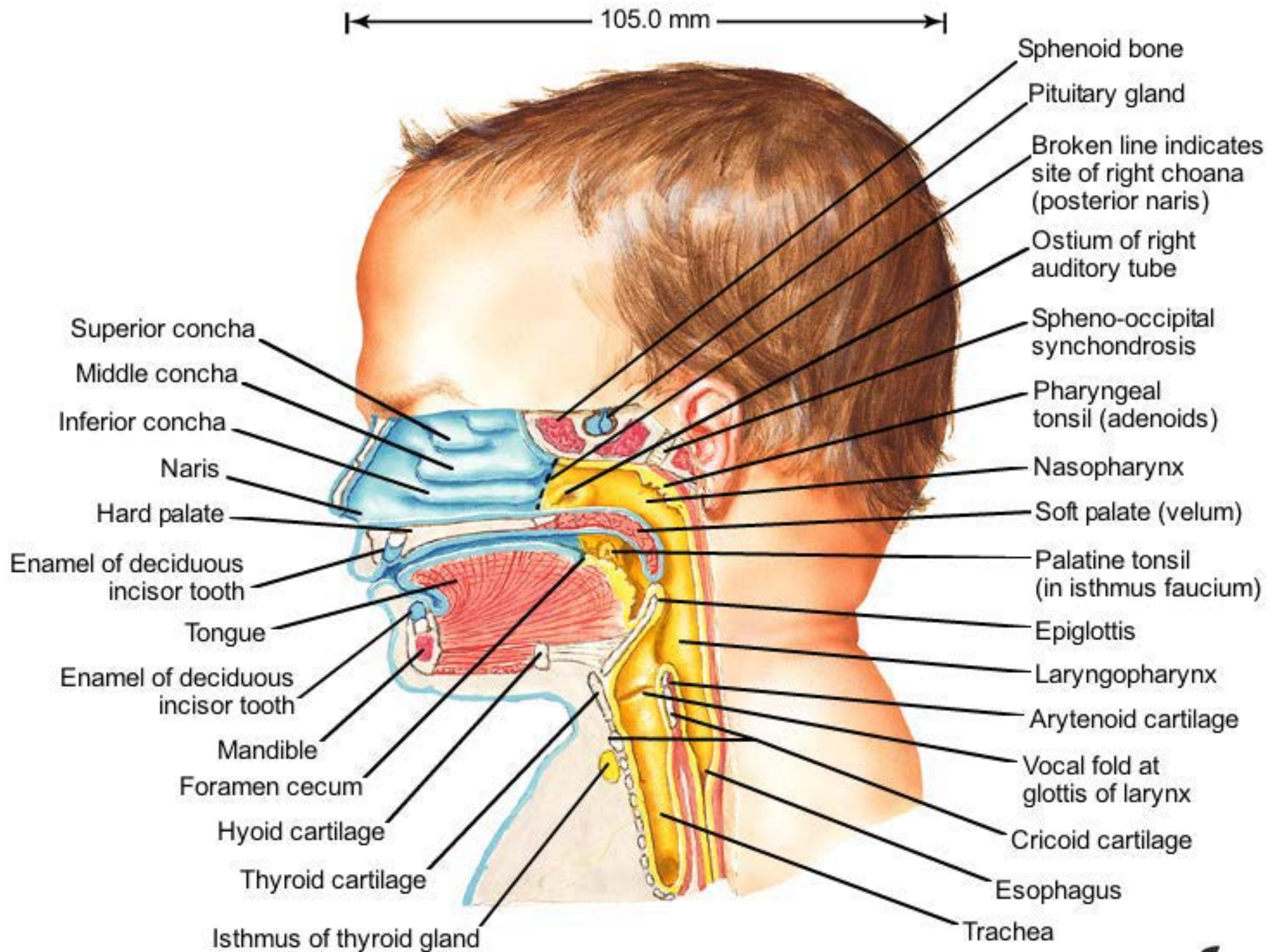




# The Newborn Upper Airway

During quiet respiration with mouth closed (partial midsagittal section with nasal septum removed)

Newborn (36 weeks)





# The Newborn Upper Airway

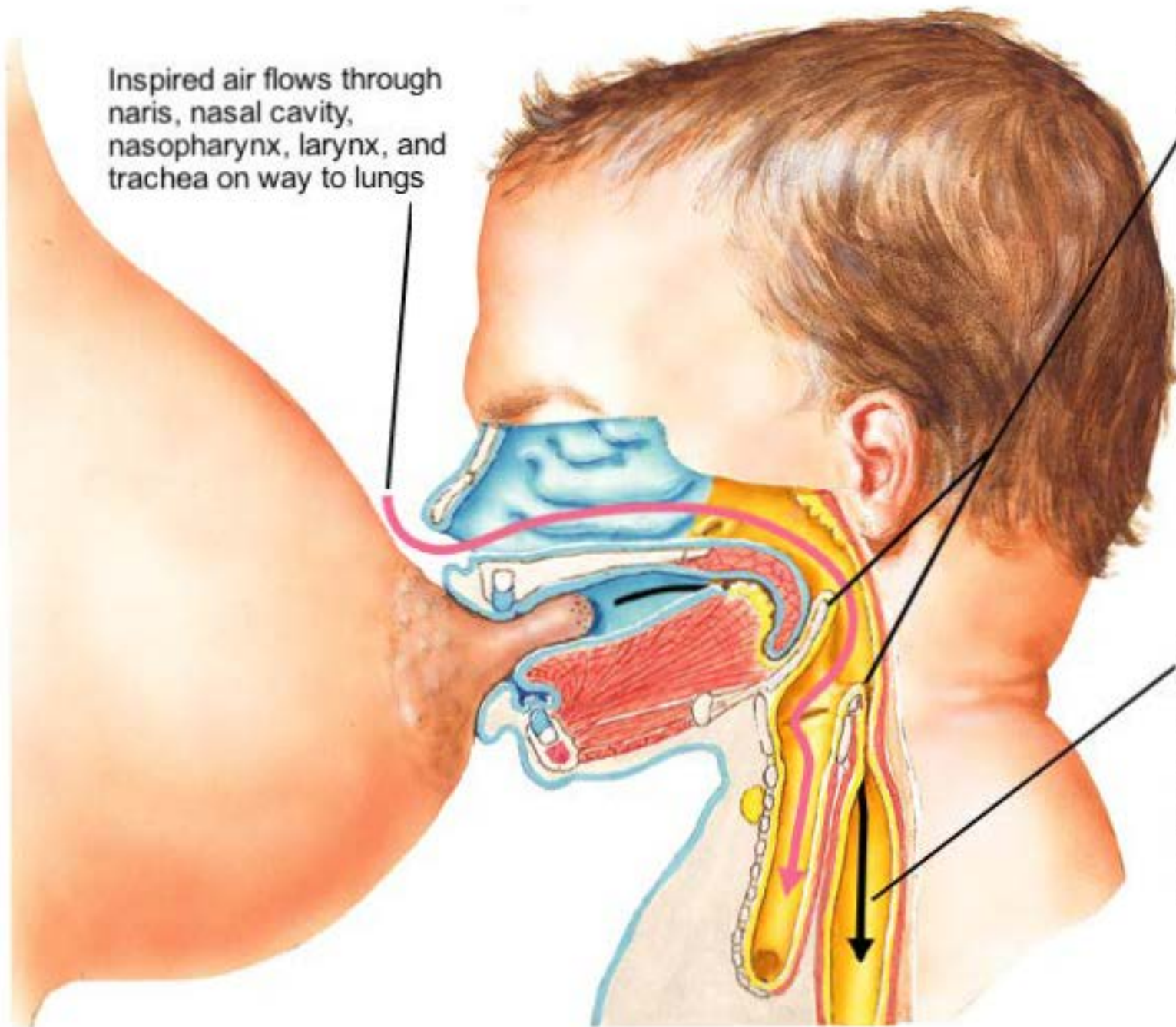
## During nursing

Newborn (36 weeks)

Inspired air flows through naris, nasal cavity, nasopharynx, larynx, and trachea on way to lungs

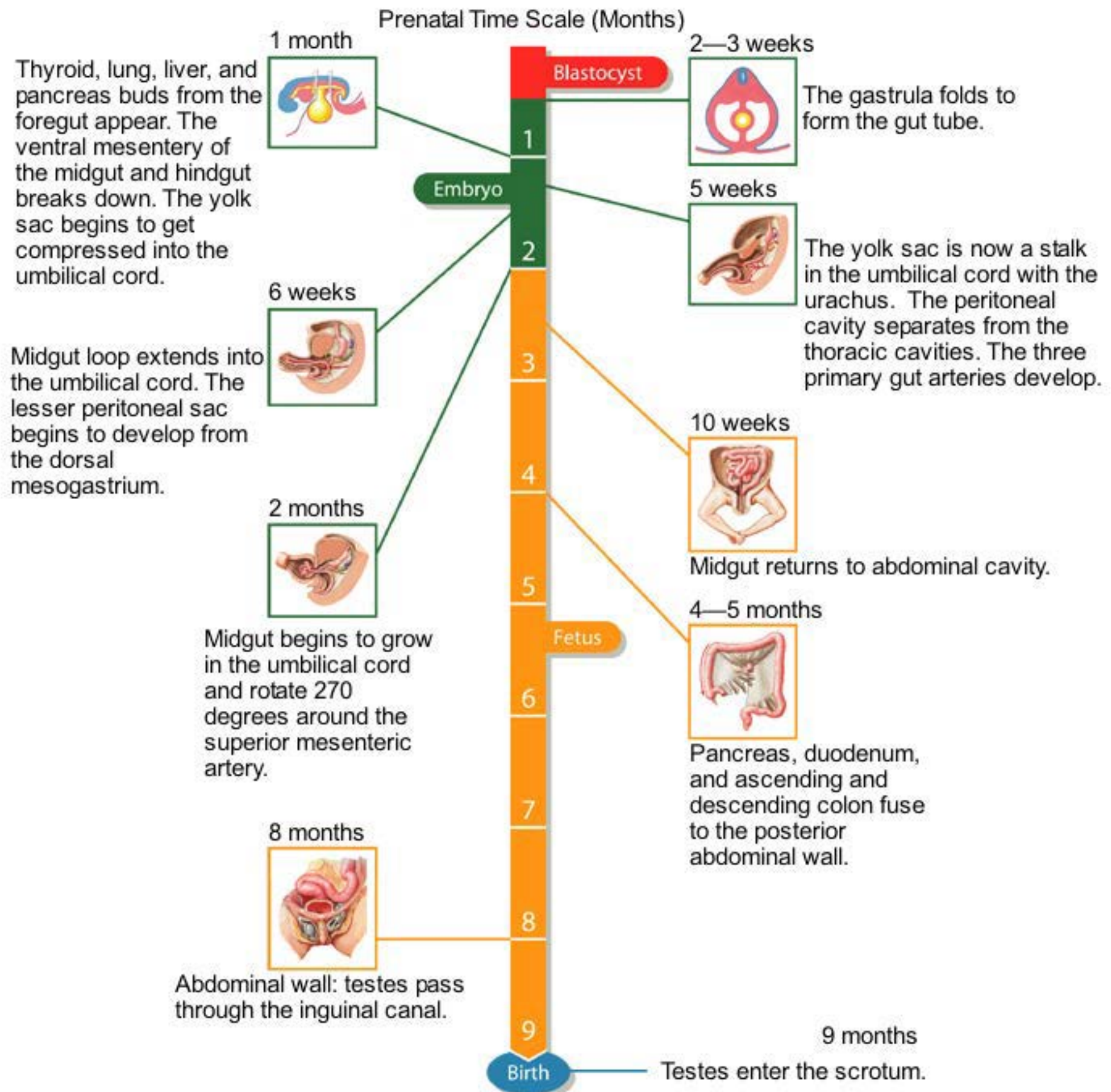
Larynx elevated into nasopharynx to permit swallowing while breathing

Suckled milk flows from oral cavity through isthmus faucium and pharynx (passing along each side of larynx) and then through esophagus on way to stomach

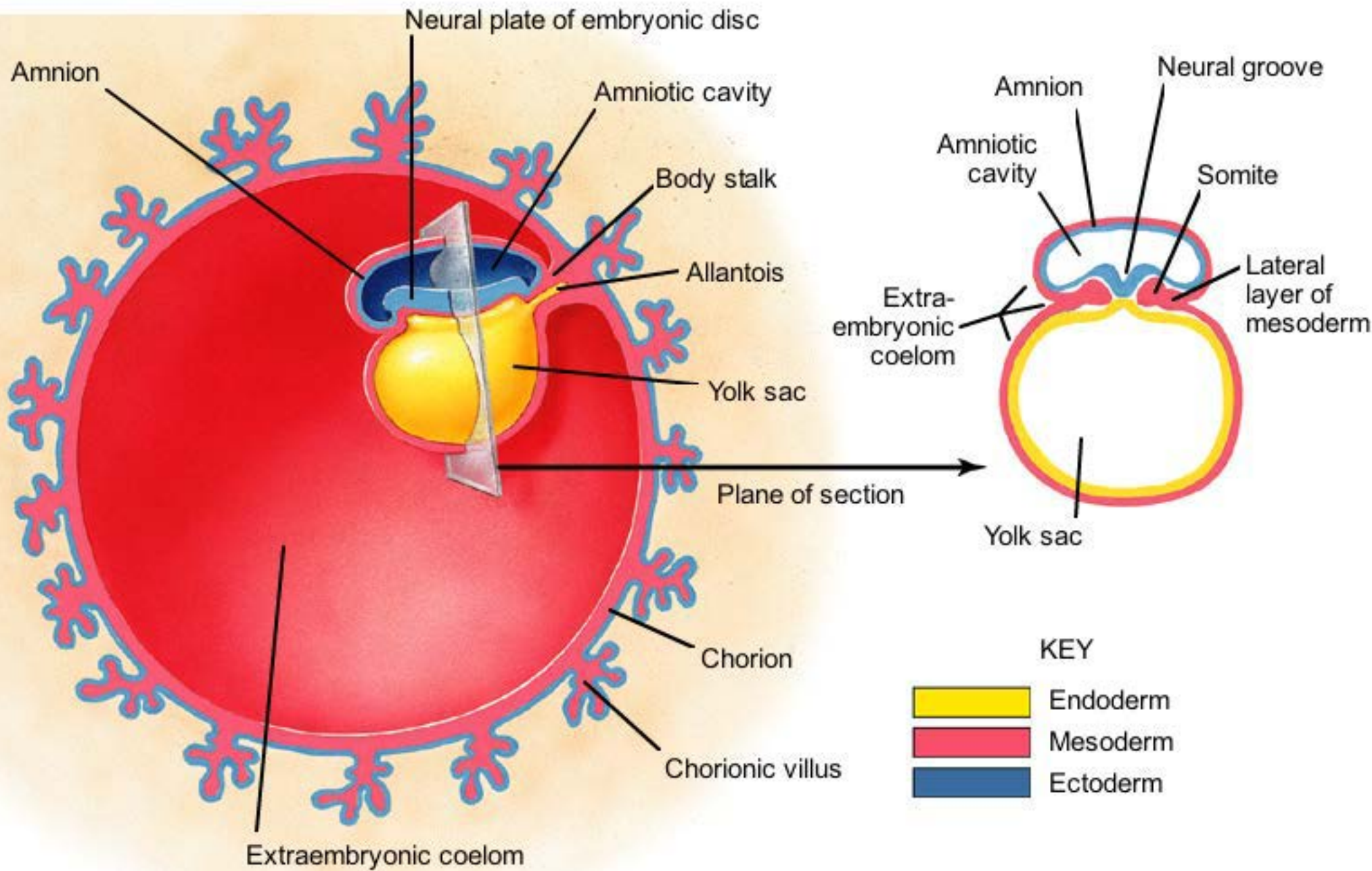




# THE GASTROINTESTINAL SYSTEM AND ABDOMINAL WALL TIMELINE



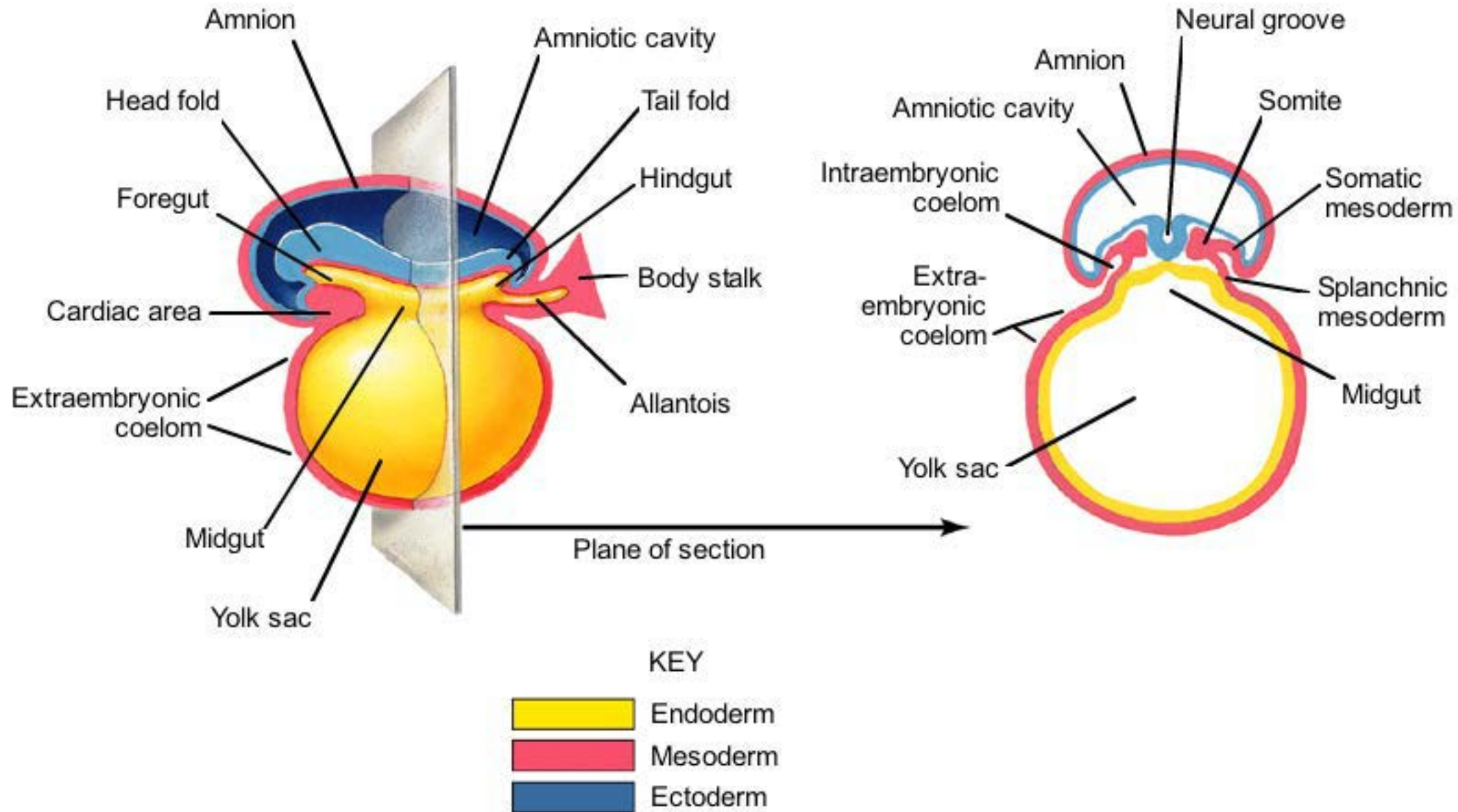
## Early Primordia





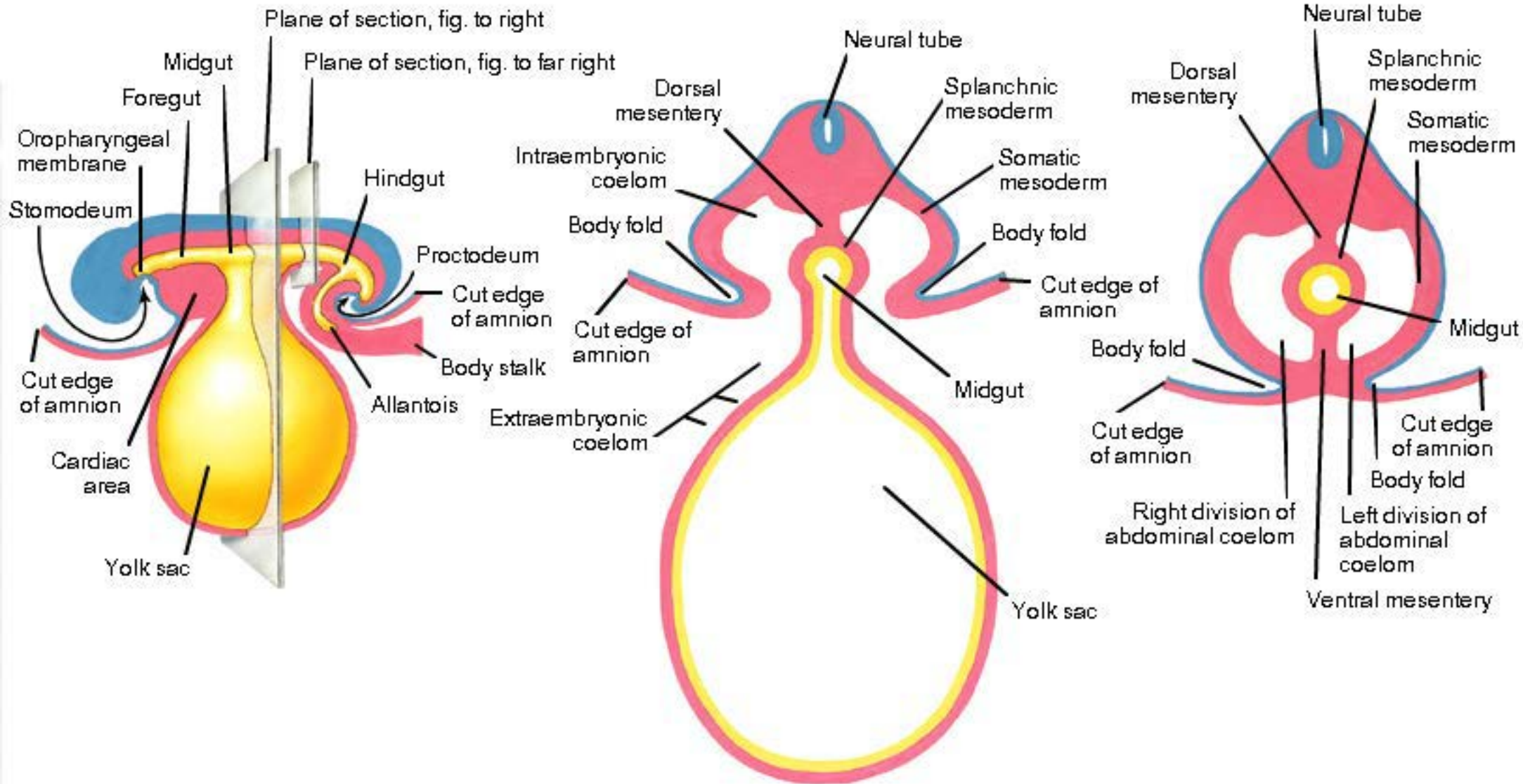
# Early Primordia

## 16 days



# Formation of the Gut Tube and Mesenteries

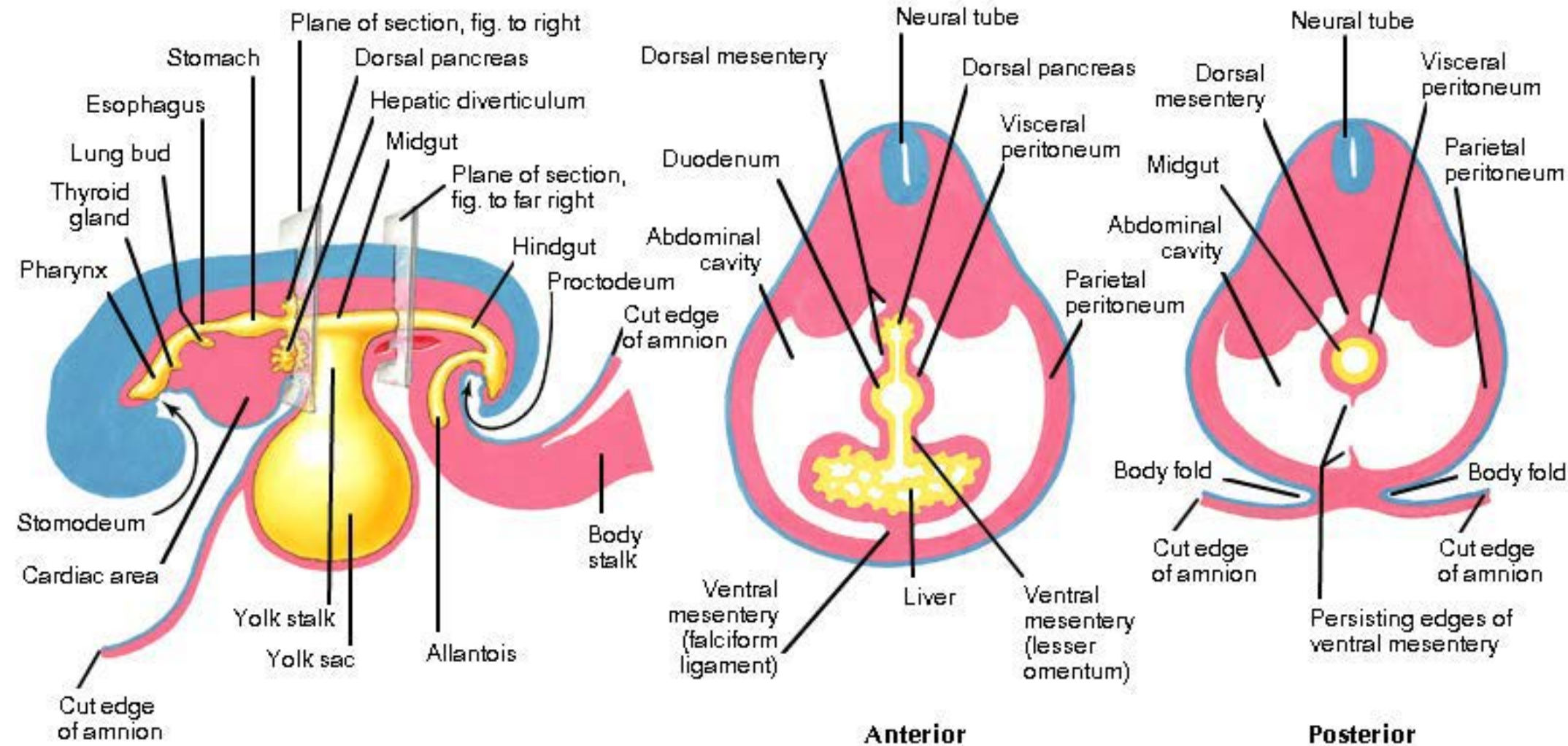
## 18 days





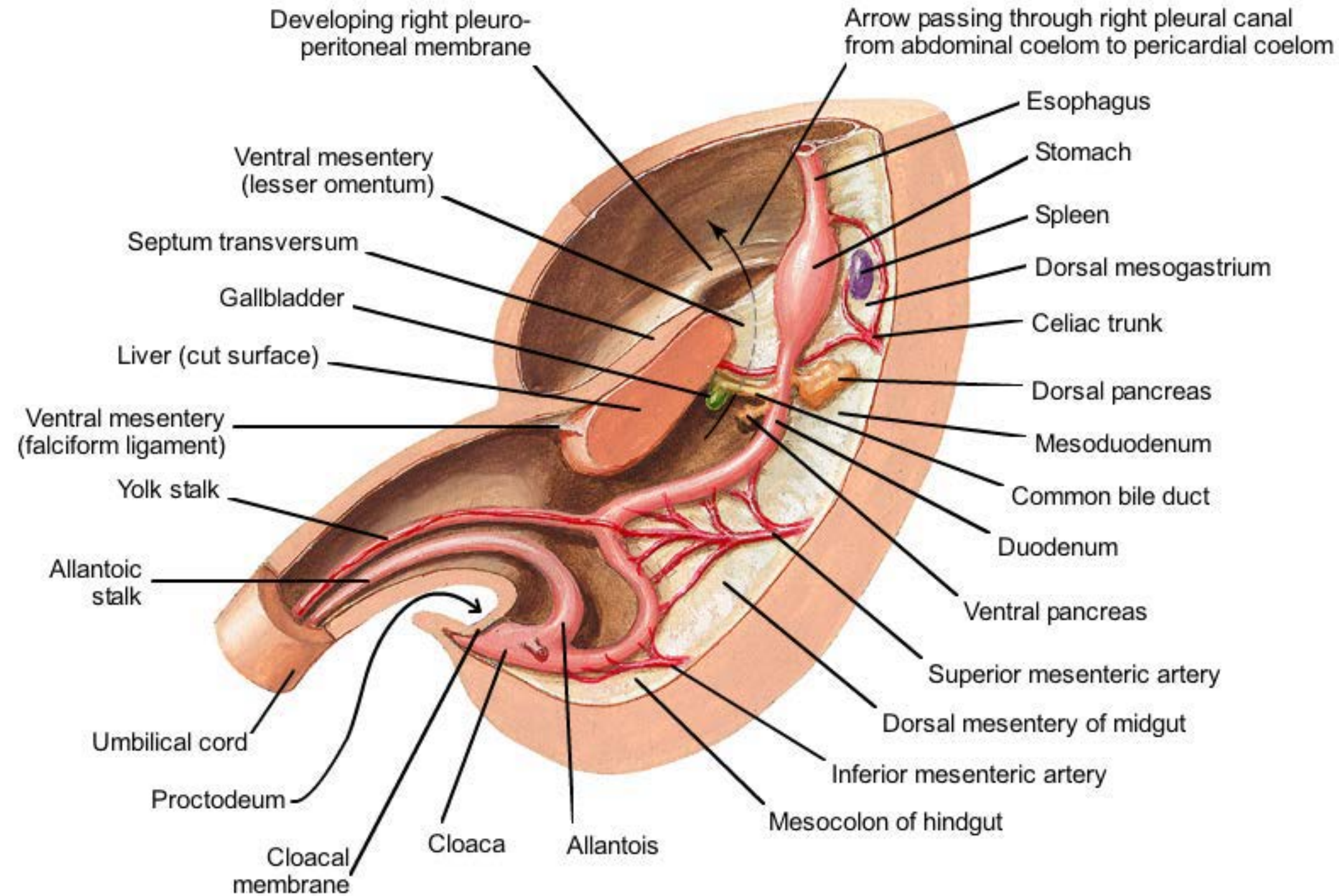
# Formation of the Gut Tube and Mesenteries

## 1 month



# Foregut, Midgut, and Hindgut

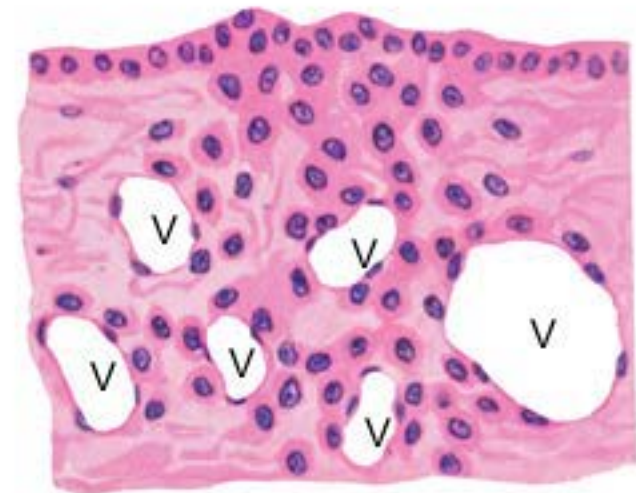
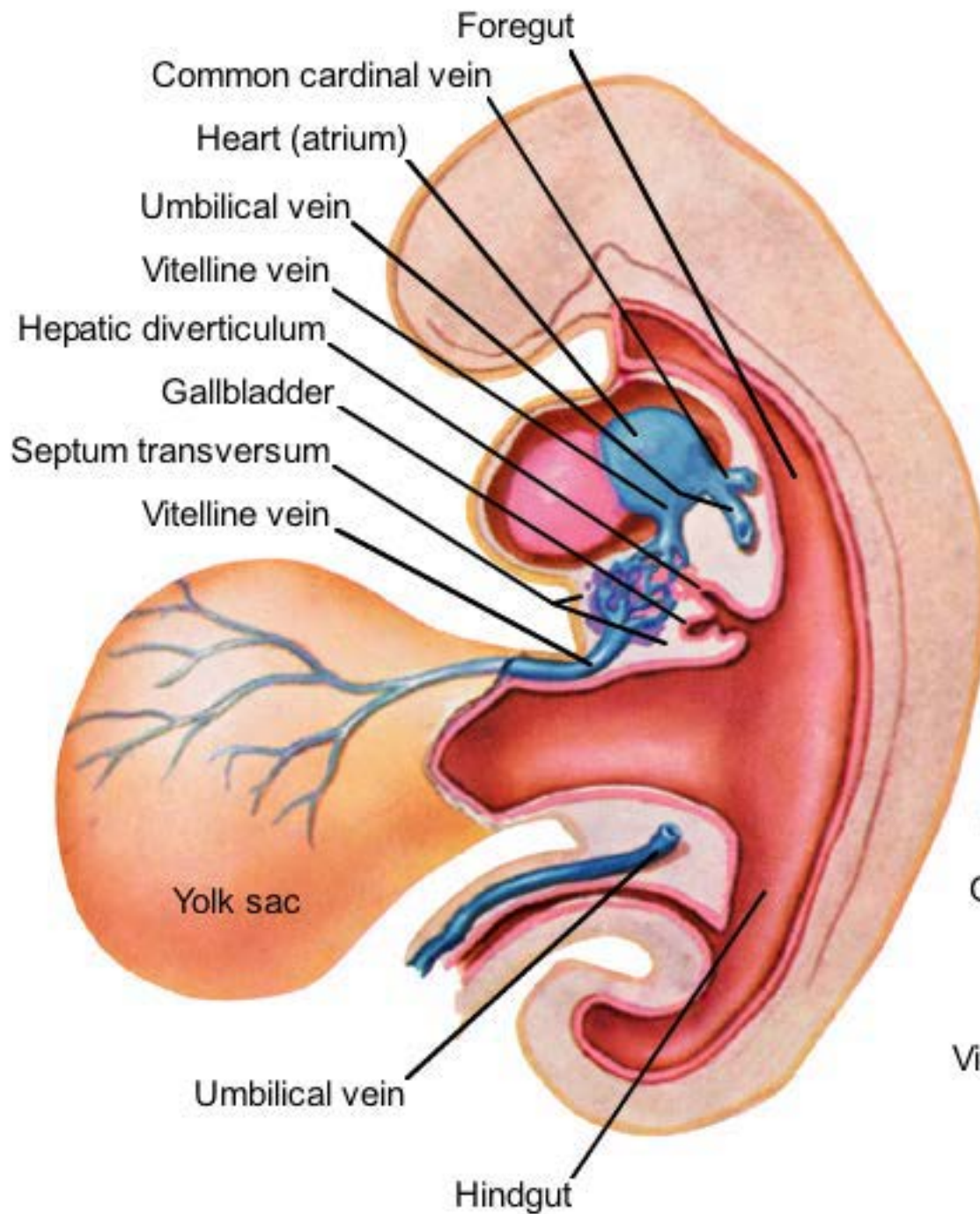
## 5 weeks



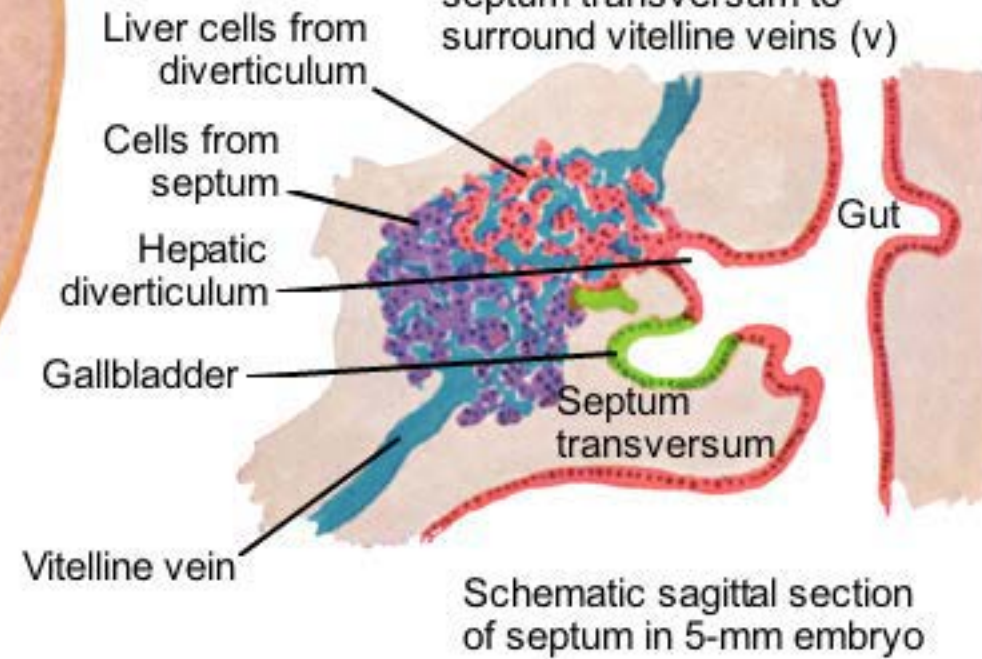


# Abdominal Veins

## Hepatic diverticulum in embryo of about 4 mm



Endodermal cells penetrating septum transversum to surround vitelline veins (v)

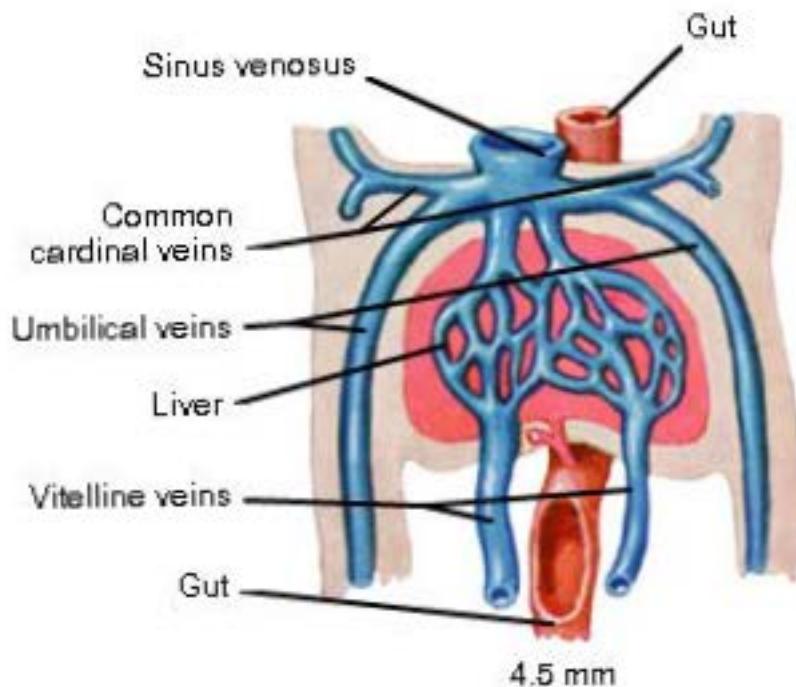


Schematic sagittal section of septum in 5-mm embryo

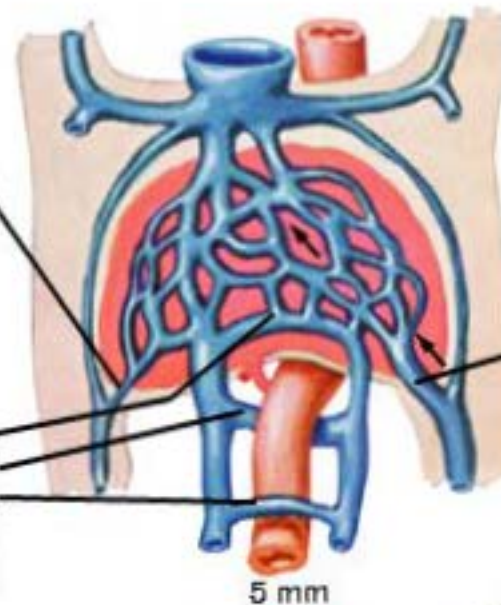


# Abdominal Veins

## Development of liver veins

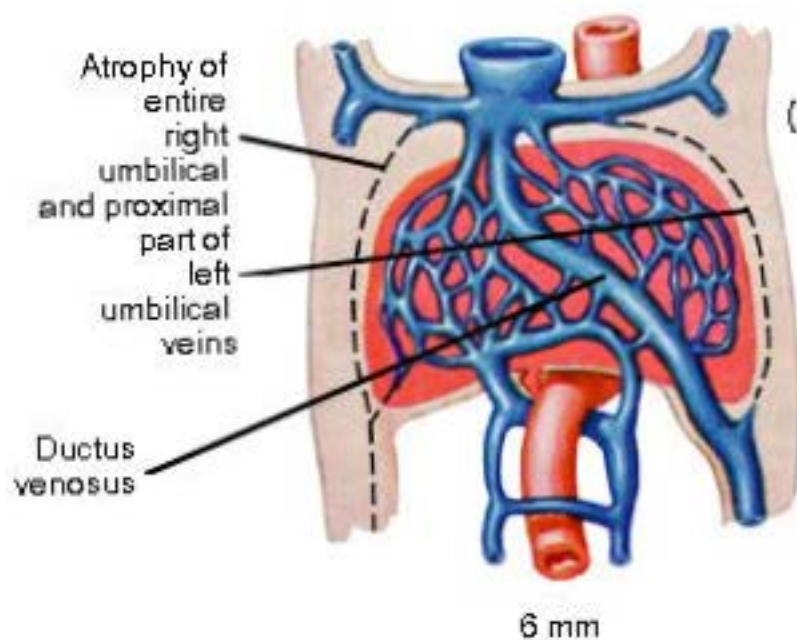


Right umbilical vein anastomosing with liver sinusoids, then atrophies

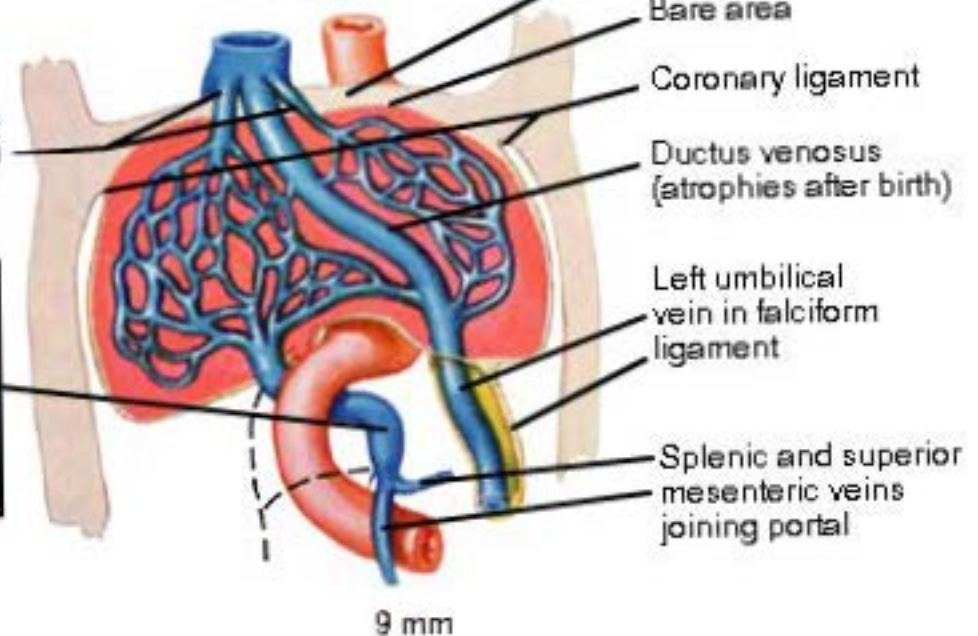


Left umbilical vein anastomosing with left vitelline vein via liver sinusoids

Proximal, middle (dorsal), and distal anastomoses of vitelline veins



Hepatic veins (proximal vitellines)

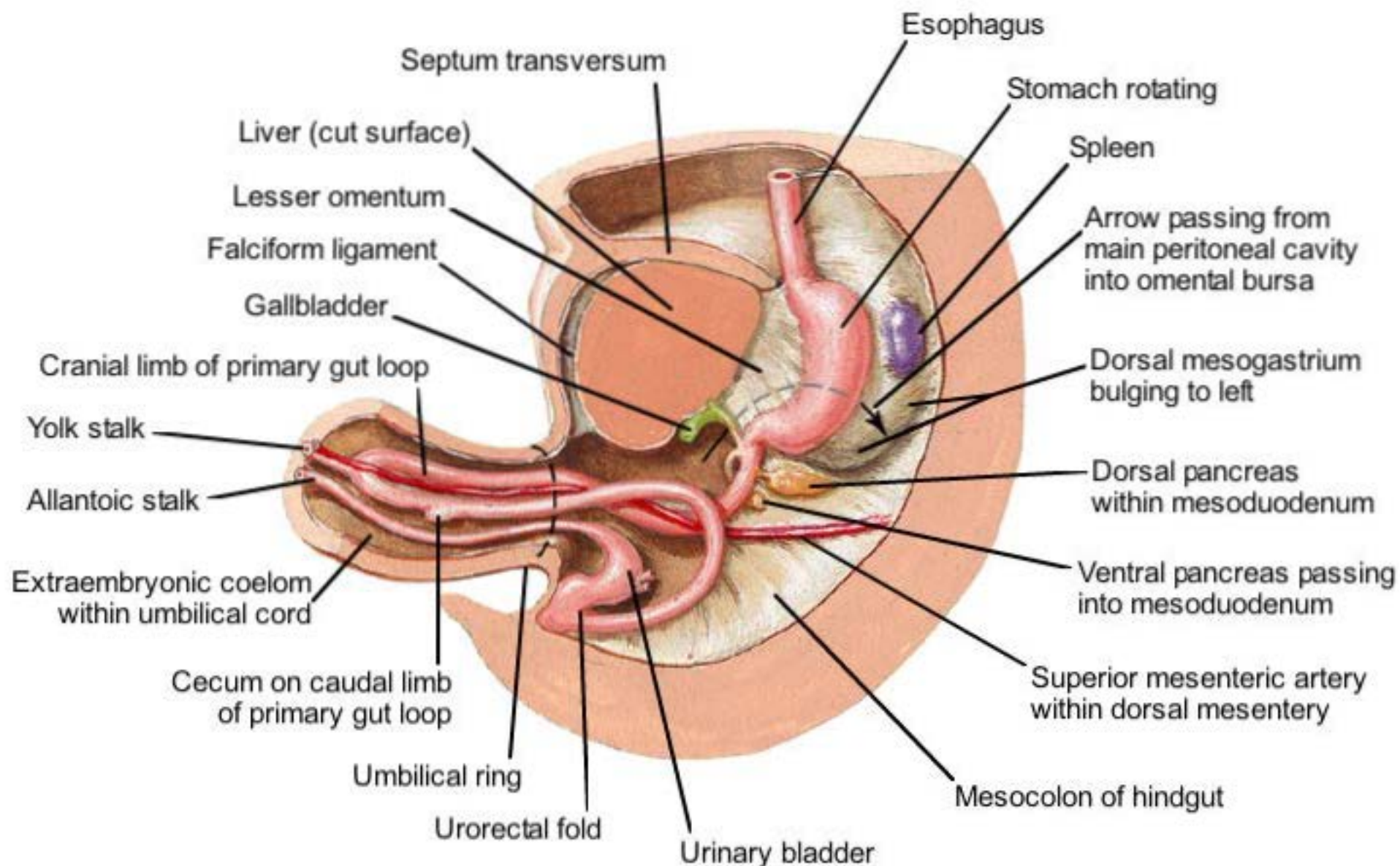


Portal vein formed from portions of right and left vitellines and middle anastomosis



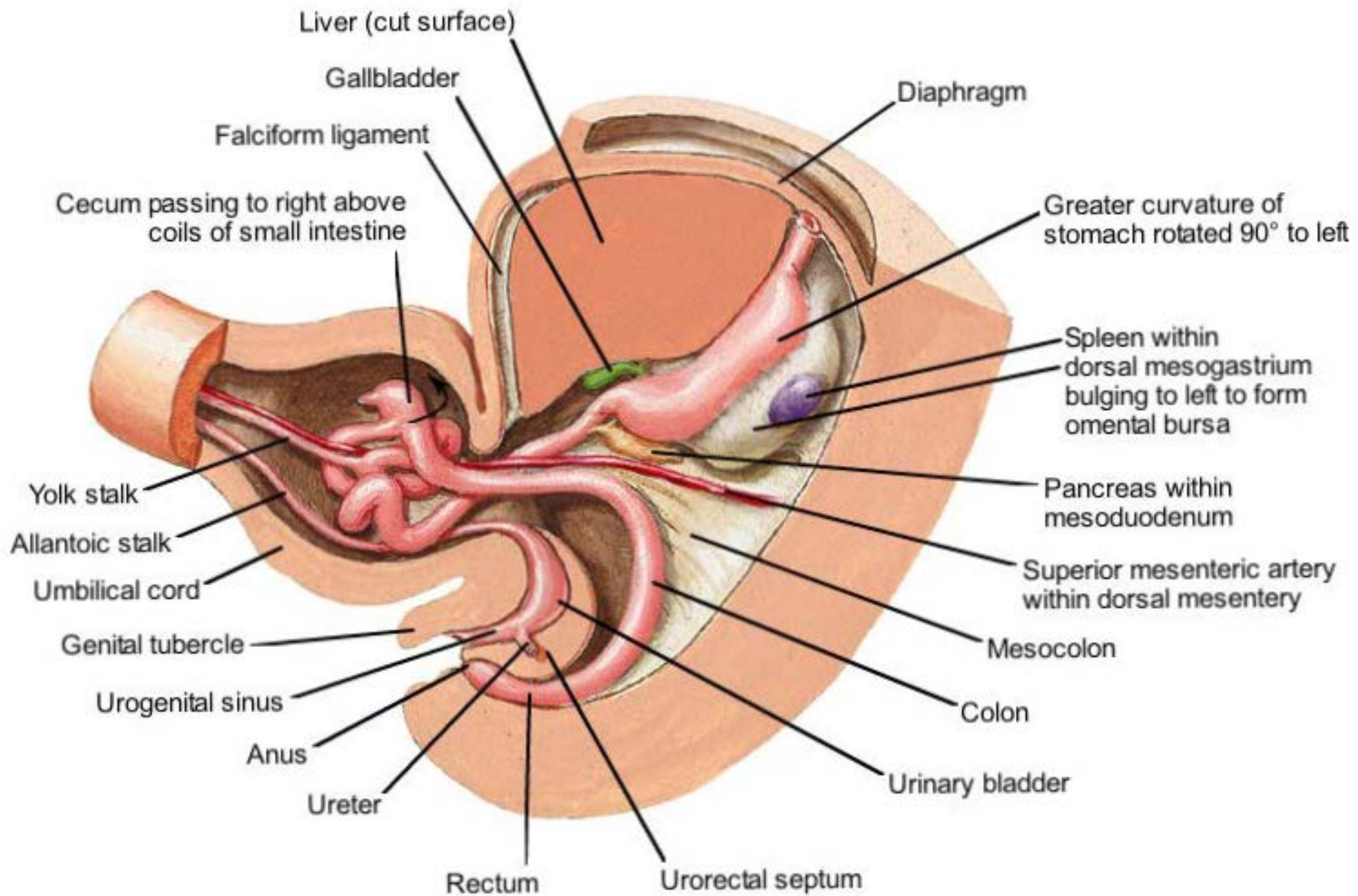
# Foregut and Midgut Rotations

## 6 weeks



# Foregut and Midgut Rotations

## 8 weeks





# Merkel's Diverticulum

Meckel's diverticulum

Meckel's diverticulum with fibrous cord extending to umbilicus

Fibrous cord connecting small intestine with umbilicus

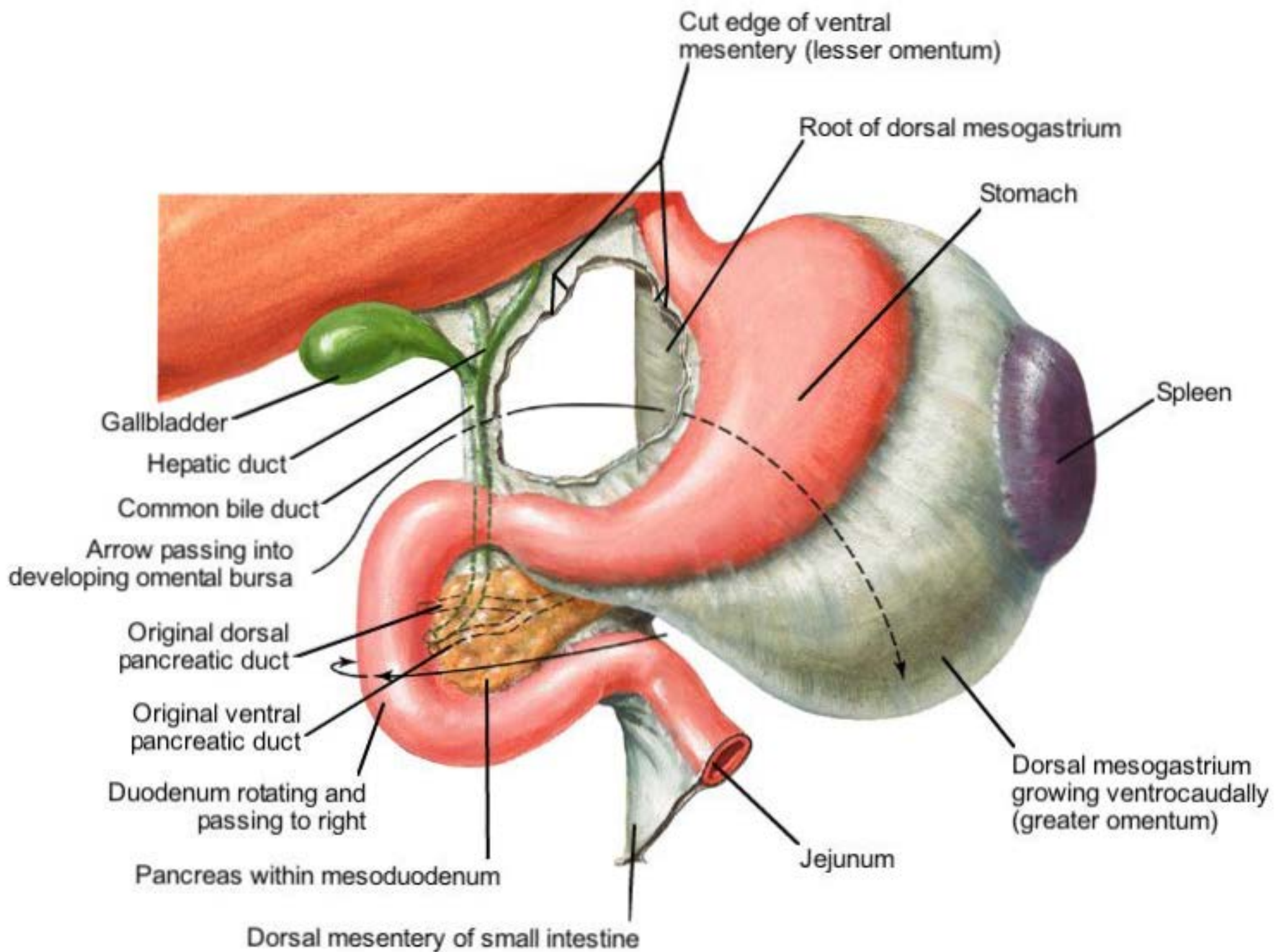
Umbilicointestinal fistula

Umbilical sinus

Fibrous cord with intermediate cyst

# Lesser Peritoneal Sac

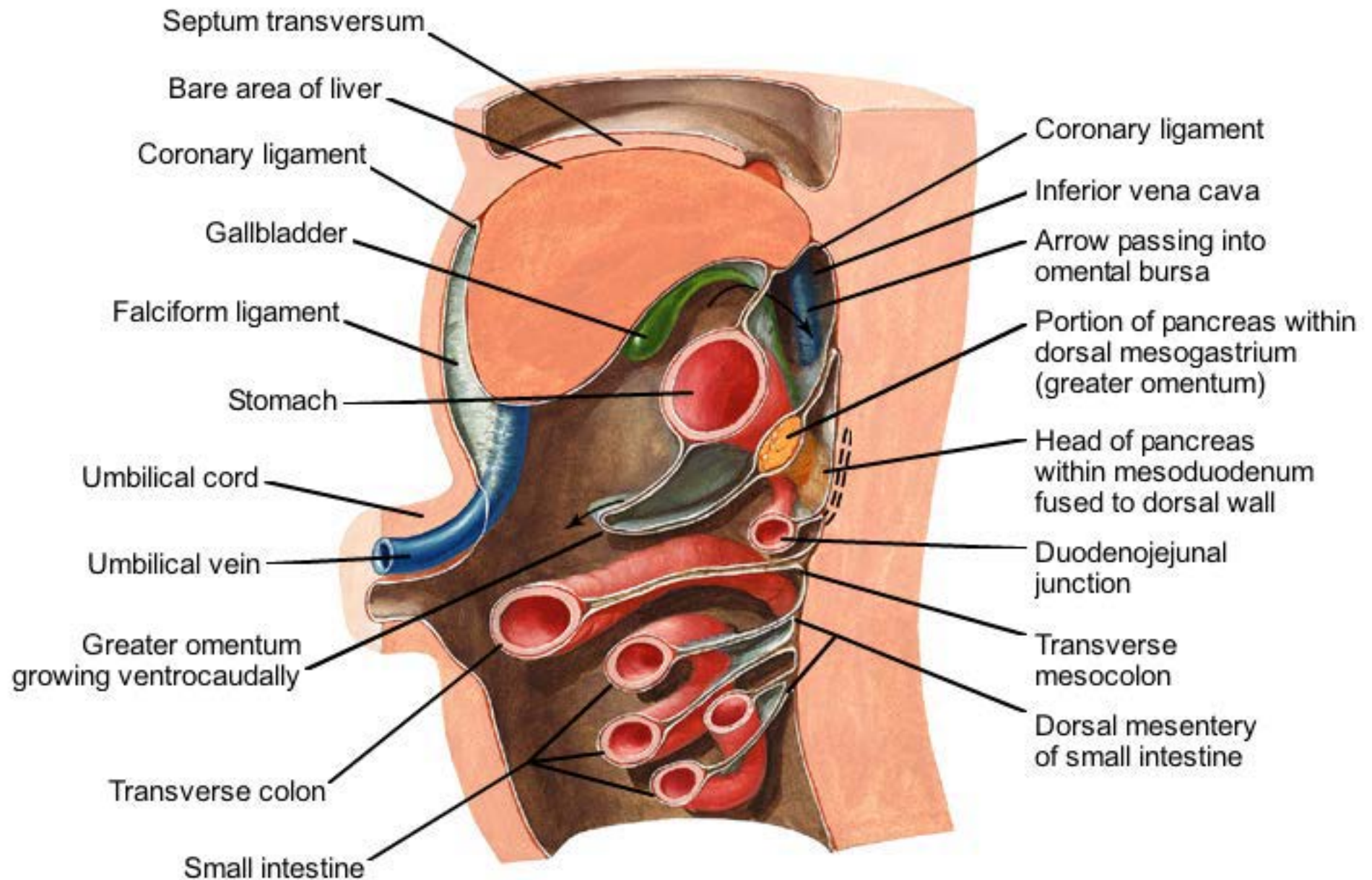
2 months





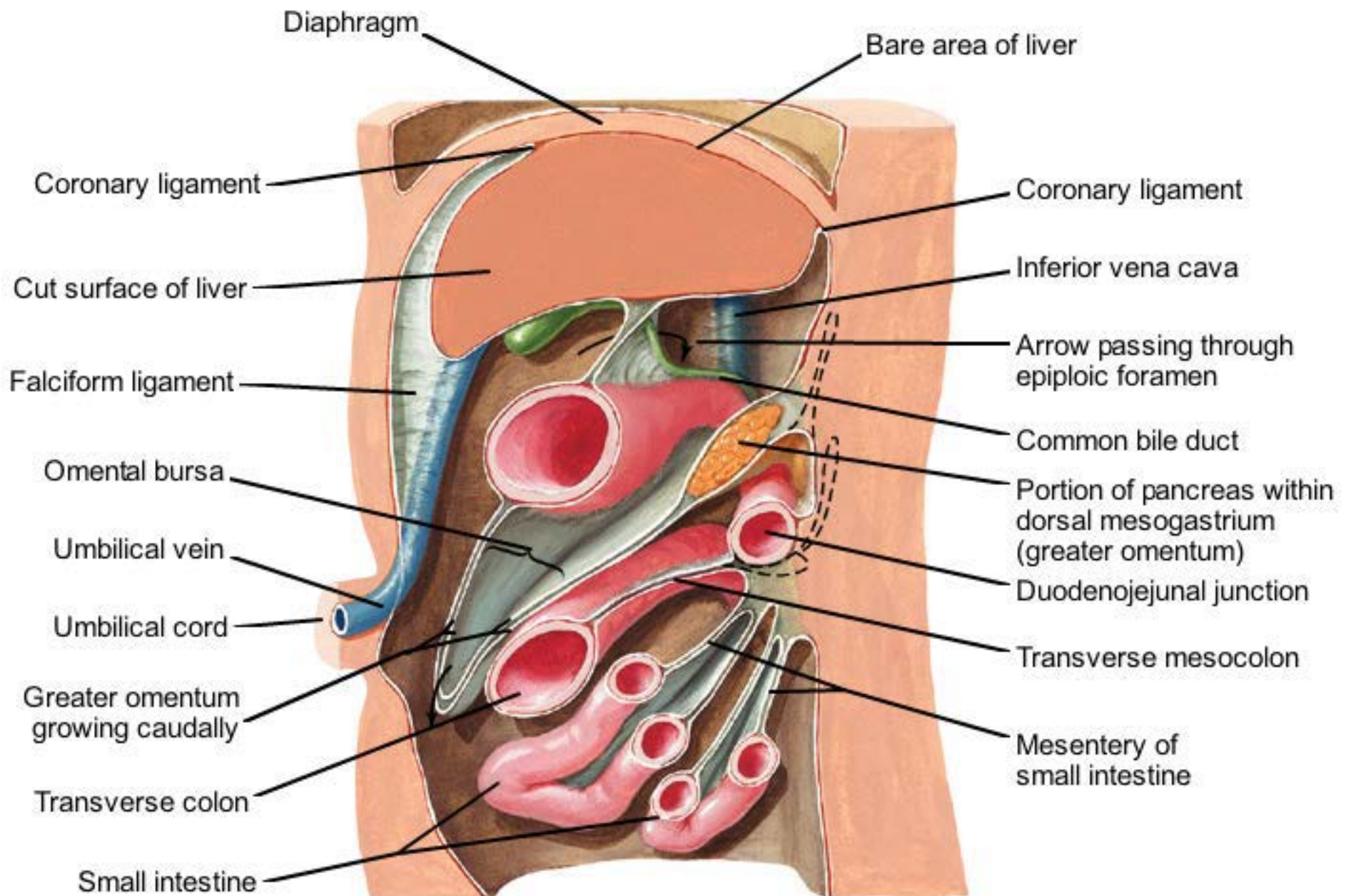
# Lesser Peritoneal Sac

## 2 to 3 months



# Introduction to the Retroperitoneal Concept

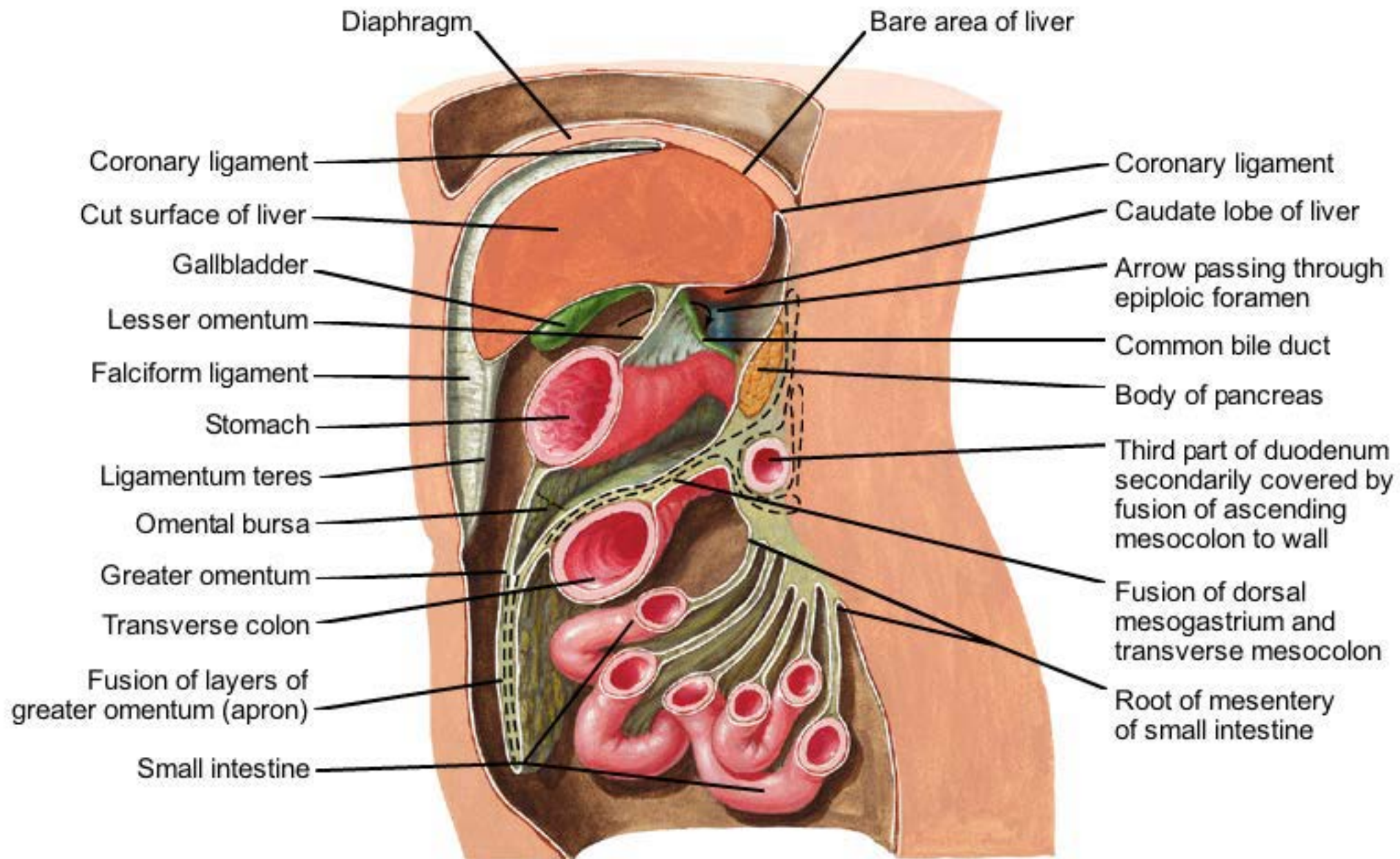
## 3 to 4 months





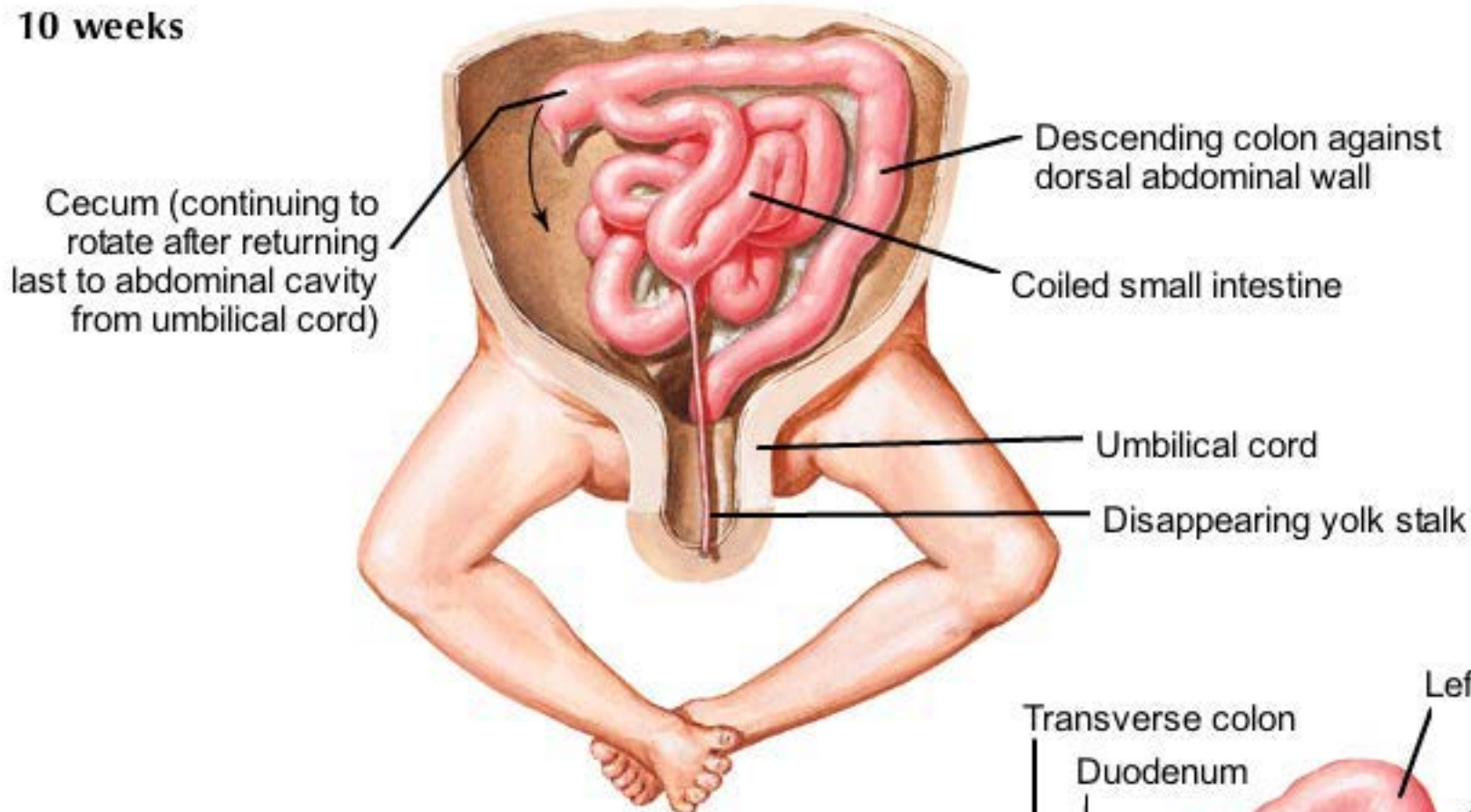
# Introduction to the Retroperitoneal Concept

## Adult relationships

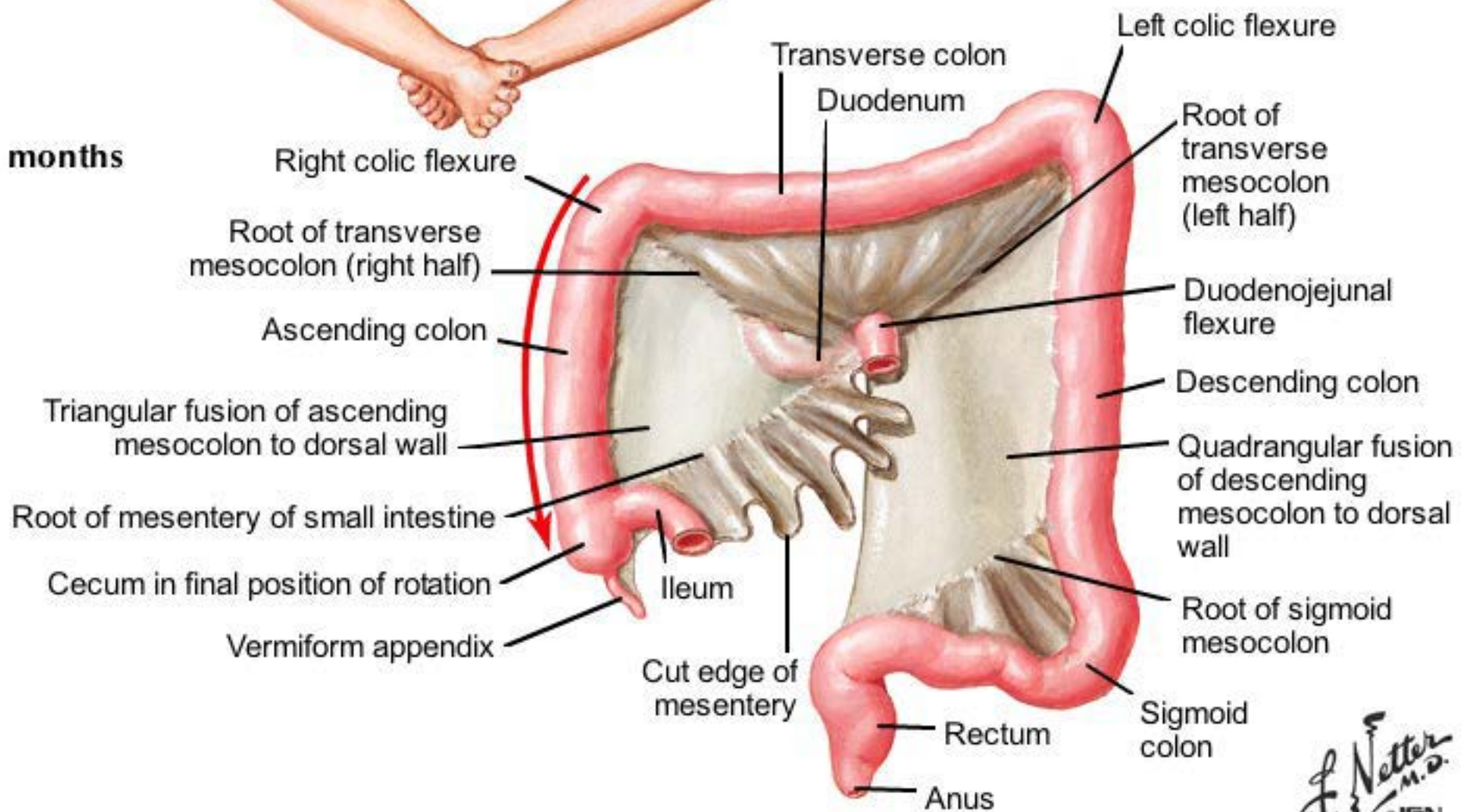


# Midgut Loop

**10 weeks**

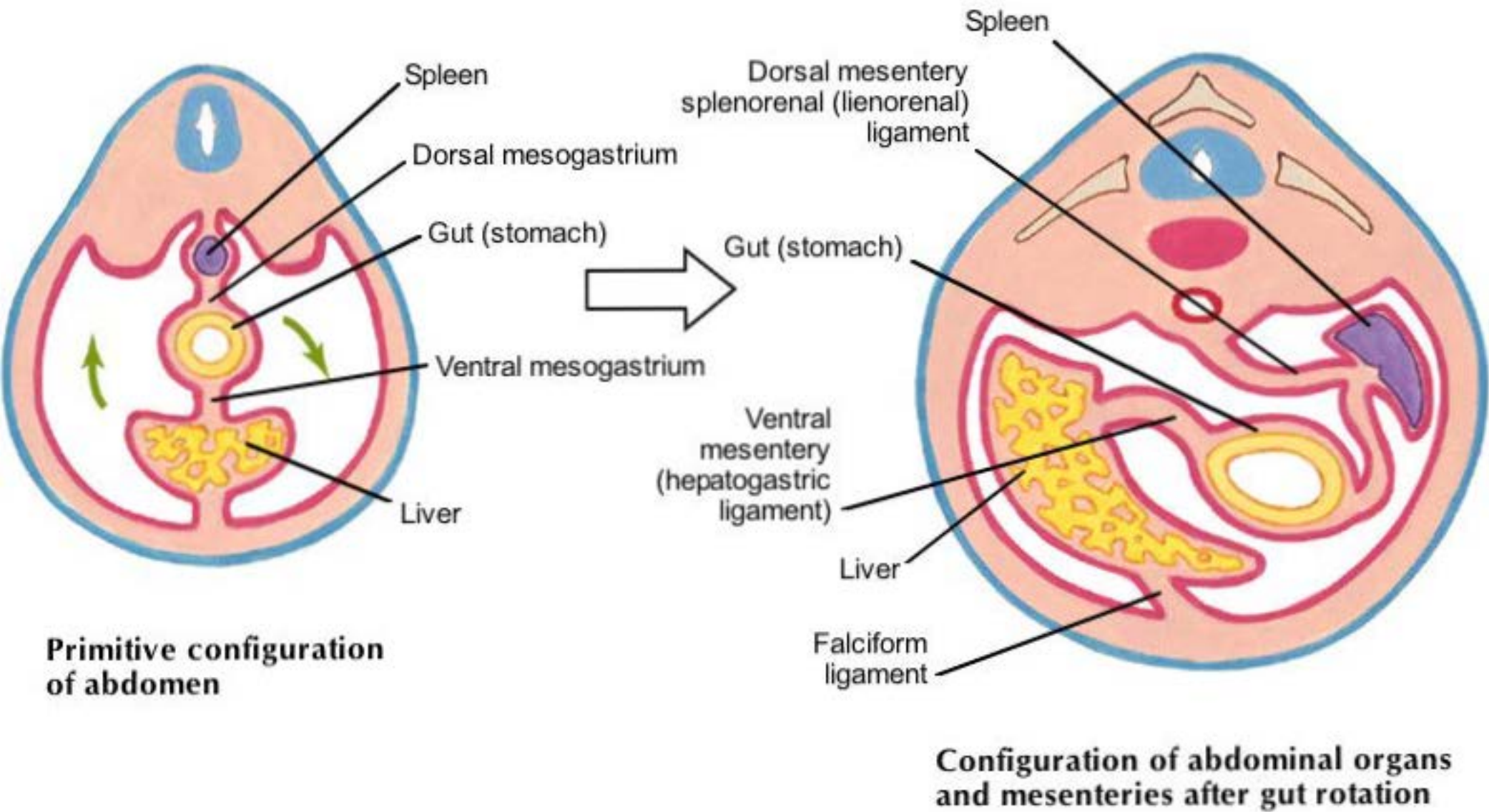


**4 to 5 months**

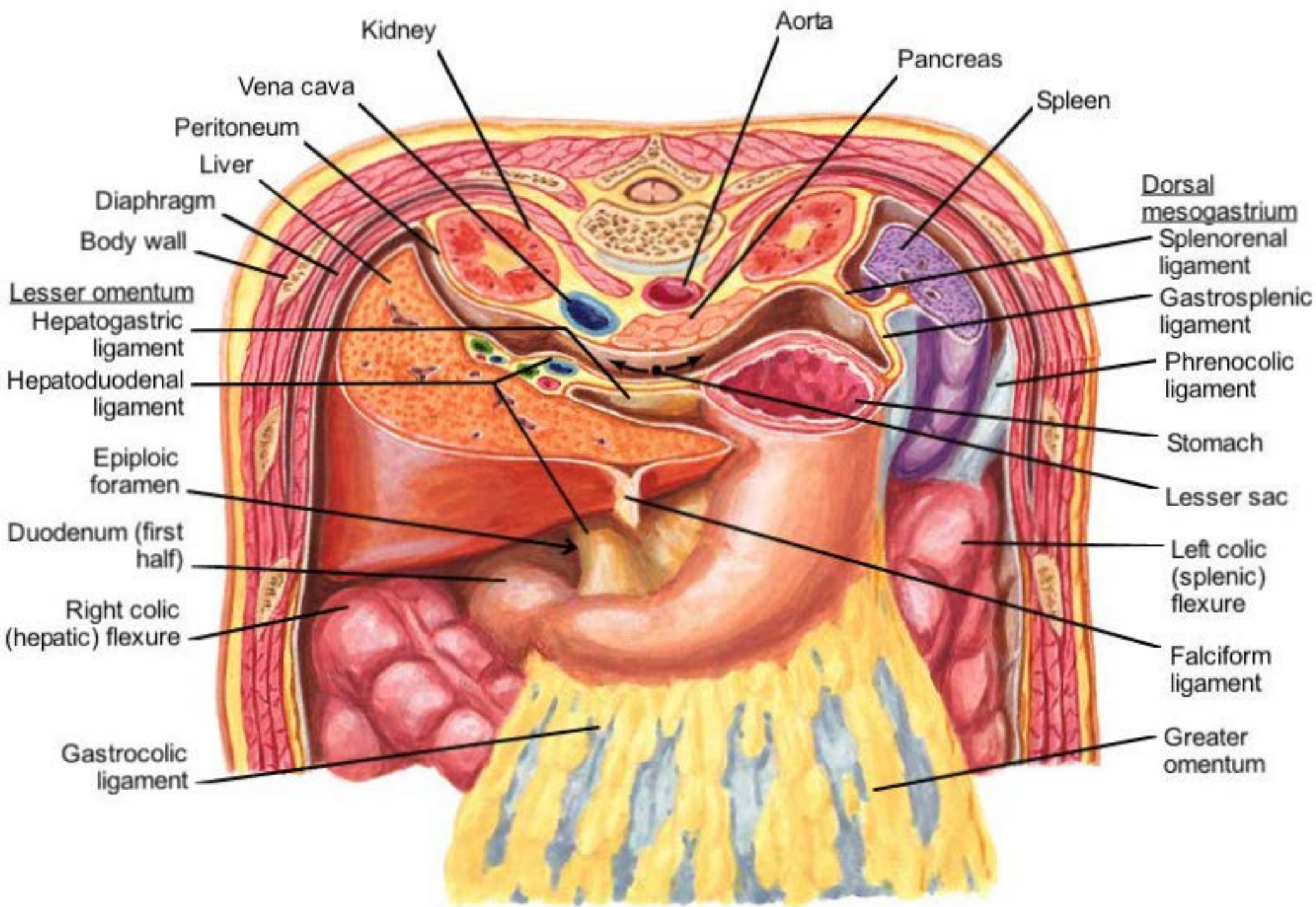




# Abdominal Ligaments

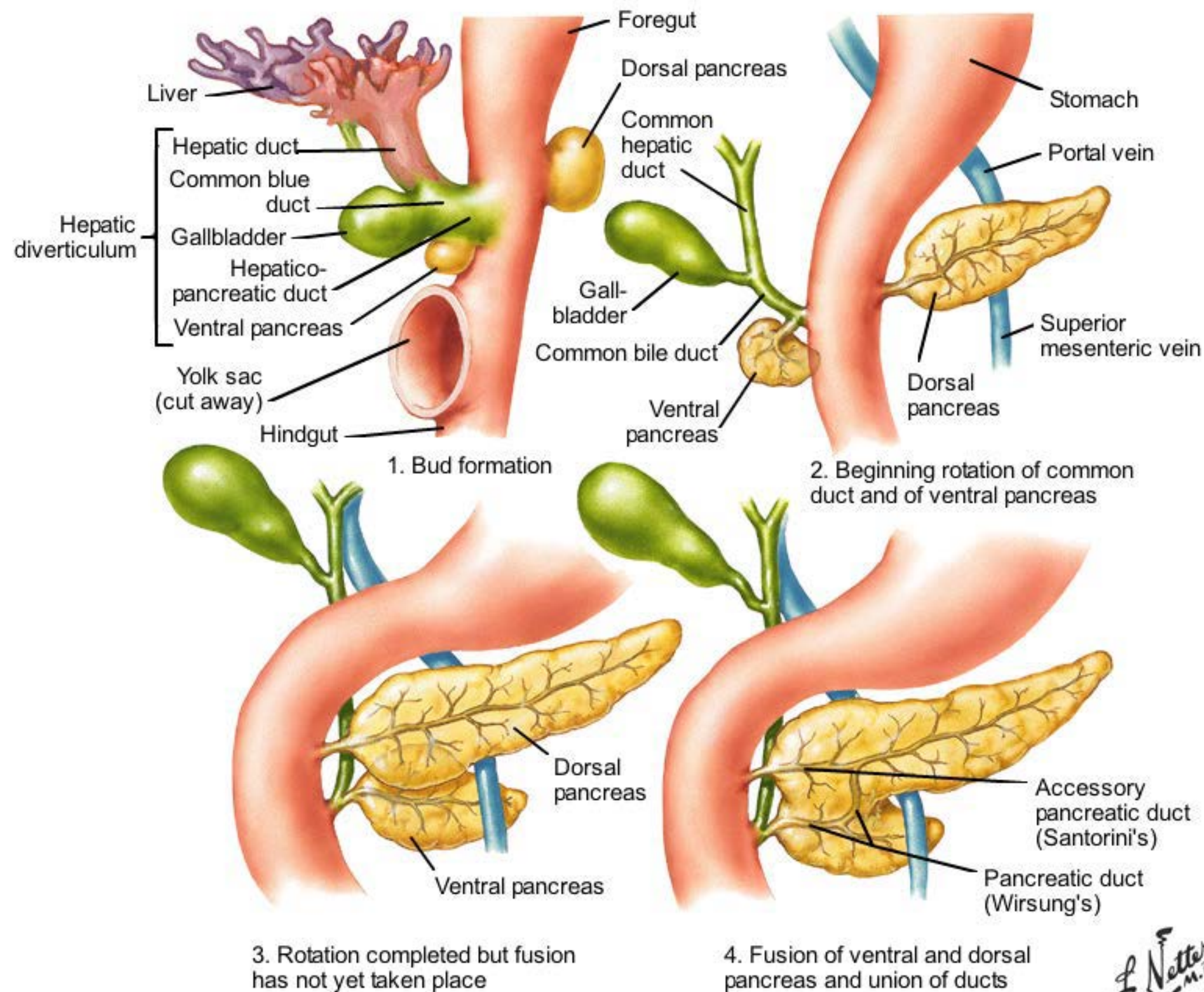


## Abdominal Ligaments



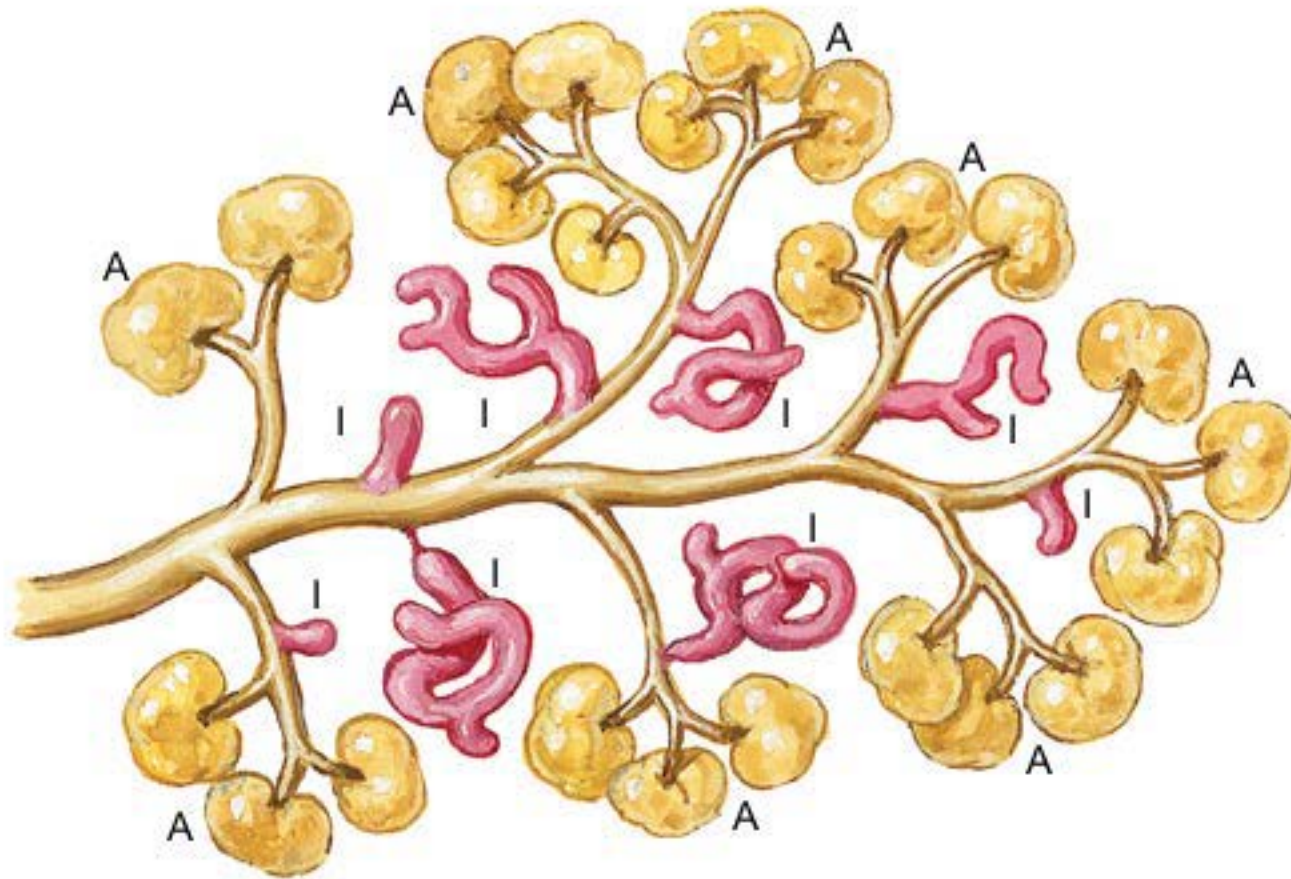


# Abdominal Foregut Organ Development



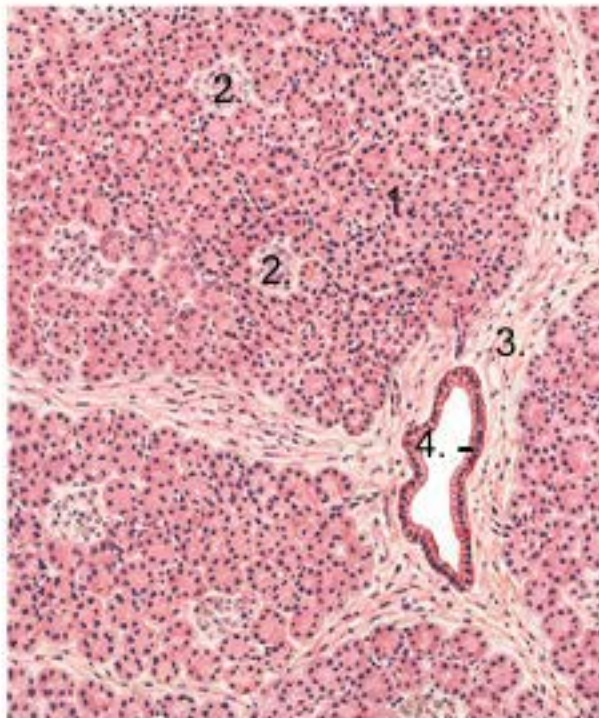


# Development of Pancreatic Acini and Islets

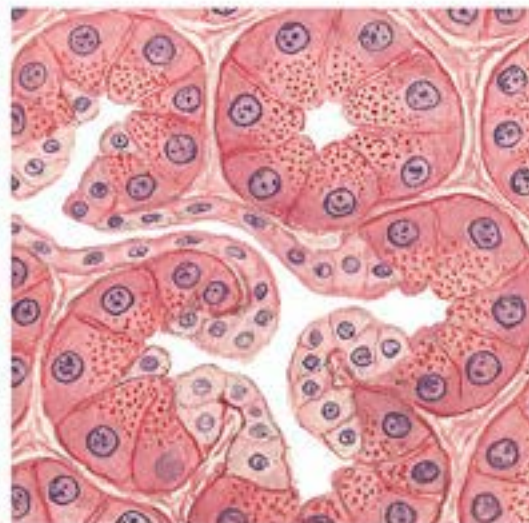


Formation of acini and islets from ducts. A-acini; I-islets in various stages of development

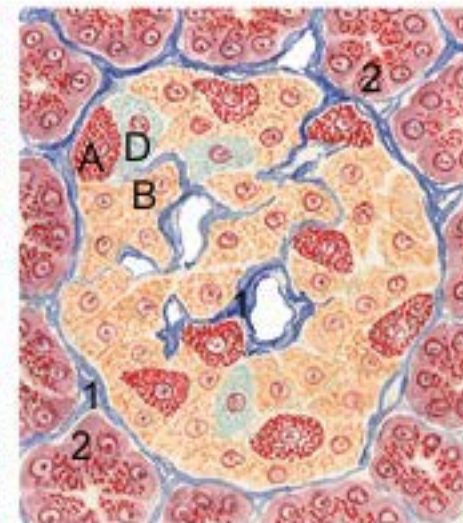
*F. Netter M.D.*  
© IGV



Low-power section of pancreas  
1. Acini, 2. islet, 3. interlobular septum, 4. interlobular duct



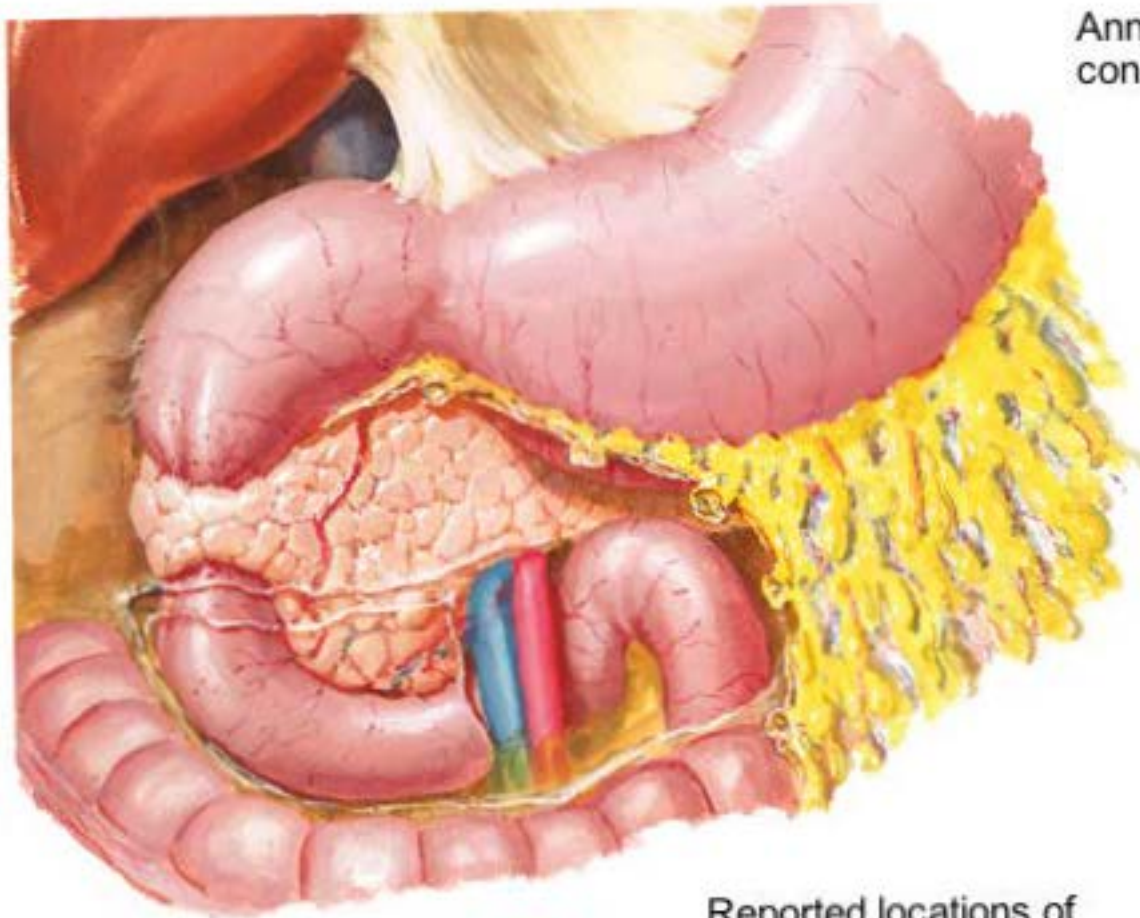
High magnification: relationship of intercalated duct and centroacinar cells to acini



Pancreatic islet  
A ( $\alpha$ -), B ( $\beta$ -) and D-cells.  
1. reticulum, 2. acini

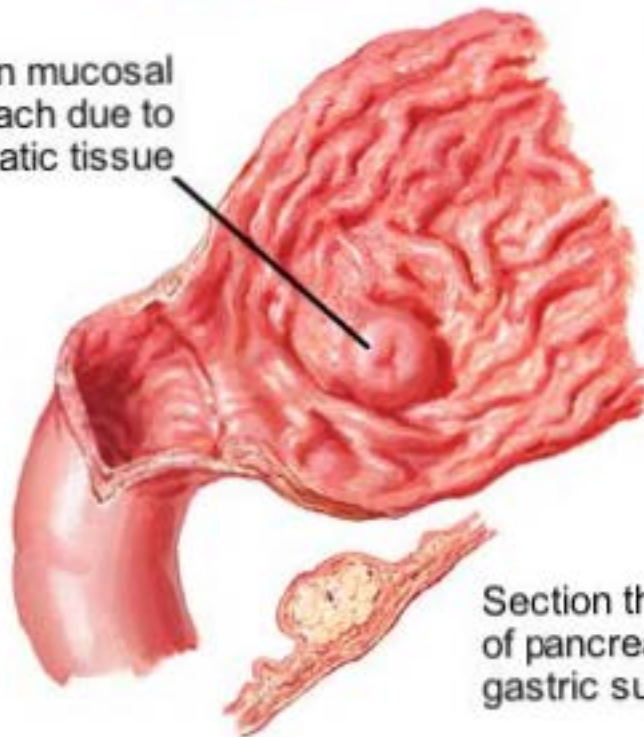


# Congenital Pancreatic Anomalies



Annular pancreas  
constricting duodenum

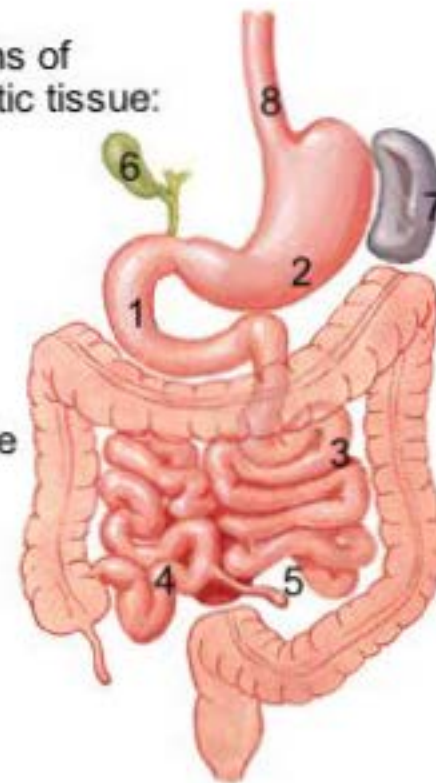
Nodule on mucosal  
aspect of stomach due to  
aberrant pancreatic tissue



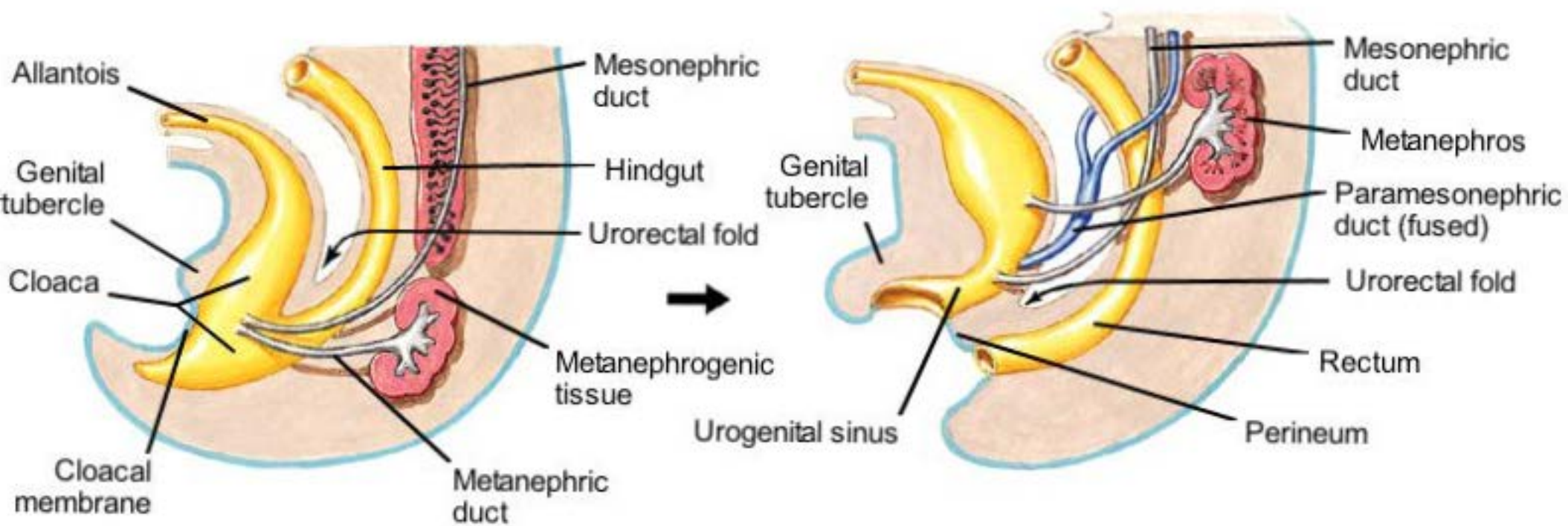
Section through nodule  
of pancreatic tissue in  
gastric submucosa

Reported locations of  
aberrant pancreatic tissue:

1. Duodenum
2. Stomach
3. Jejunum
4. Ileum
5. Meckel's diverticulum
6. Gallbladder
7. Splenic capsule
8. Esophagus



# Development of the Hindgut

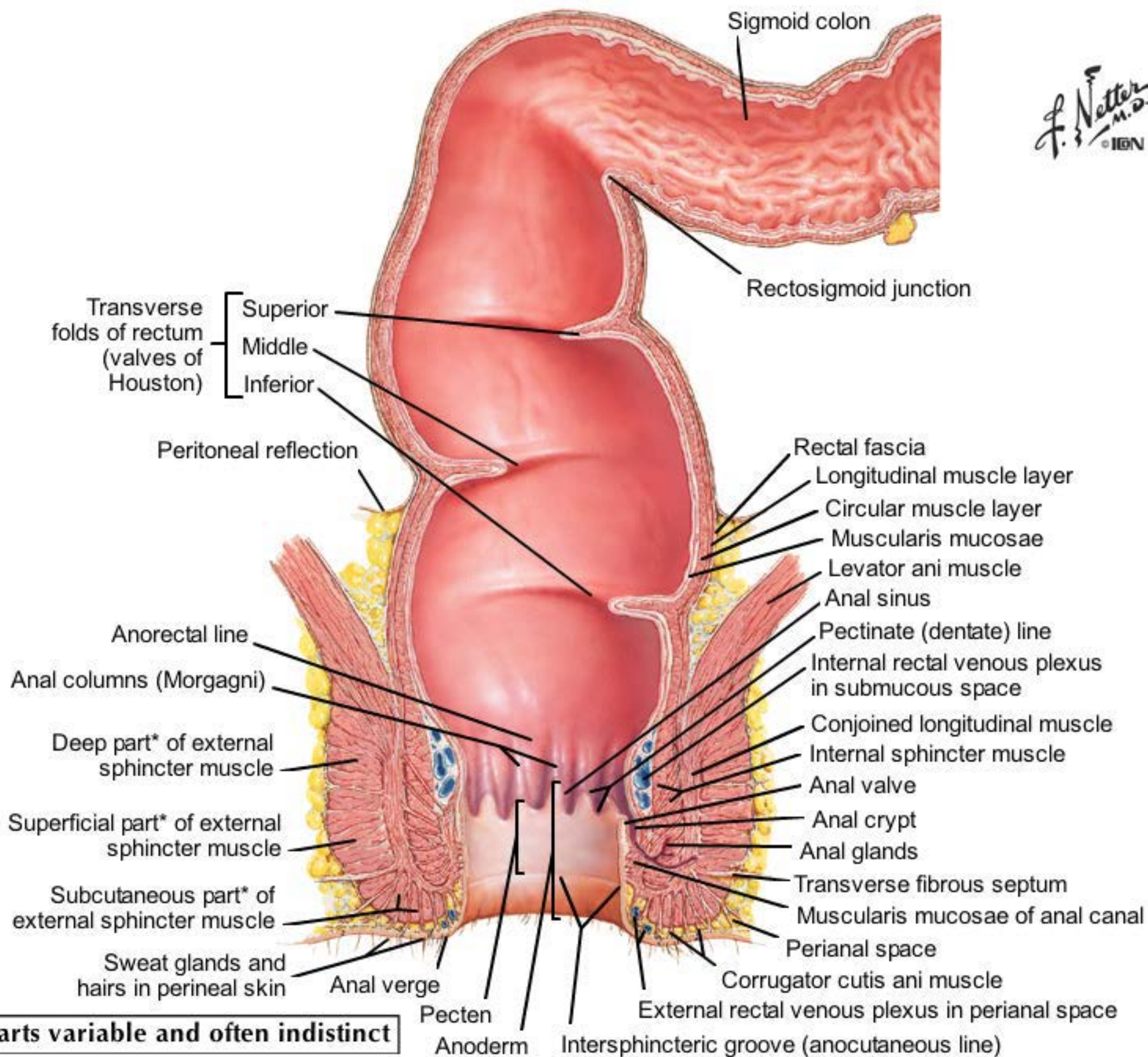




# Development of the Hindgut

## Adult rectum and anal canal

*F. Netter M.D.*  
© IGB



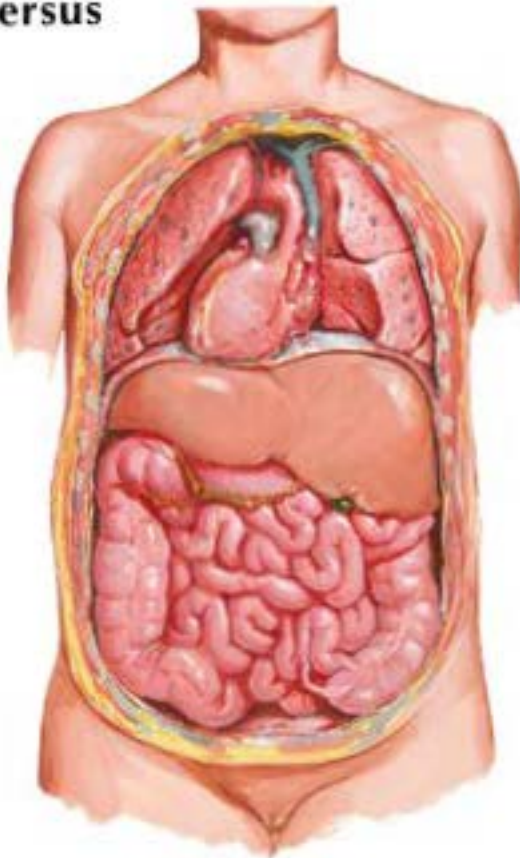
**\*Parts variable and often indistinct**



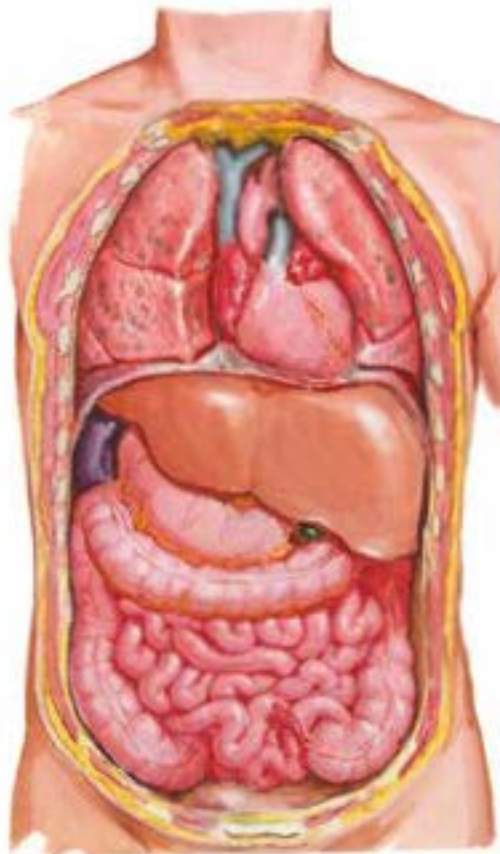
# Congenital Anomalies

## Situs inversus

Complete  
situs  
inversus



Partial  
situs  
inversus



## Duplications

Locations of alimentary tract  
duplications (\*indicates most  
common sites)



Base of tongue  
Esophagus\*  
extending into thorax from  
duodenum or jejunum  
Stomach  
Duodenum  
Transverse colon (mesenterialized)  
Jejunum  
Cecum or ascending colon  
Ileocecal region\*  
Ileum\*  
Sigmoid colon  
Rectum

## Atresia

Duodenum 23%

Jejunum 14%

Colon 5.5%

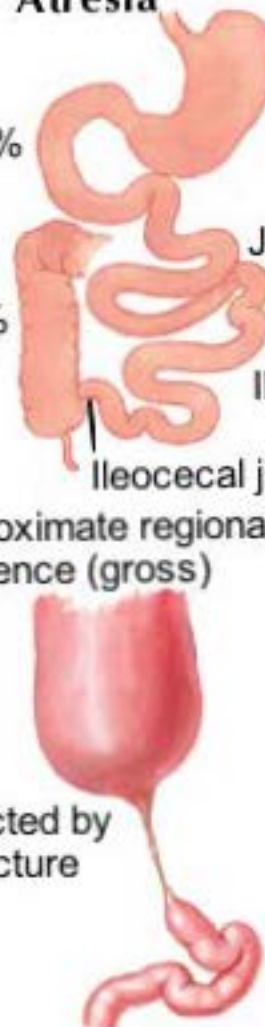
Ileum 50%

Multiple  
7.5%

Ileocecal junction 1.5%

Approximate regional  
incidence (gross)

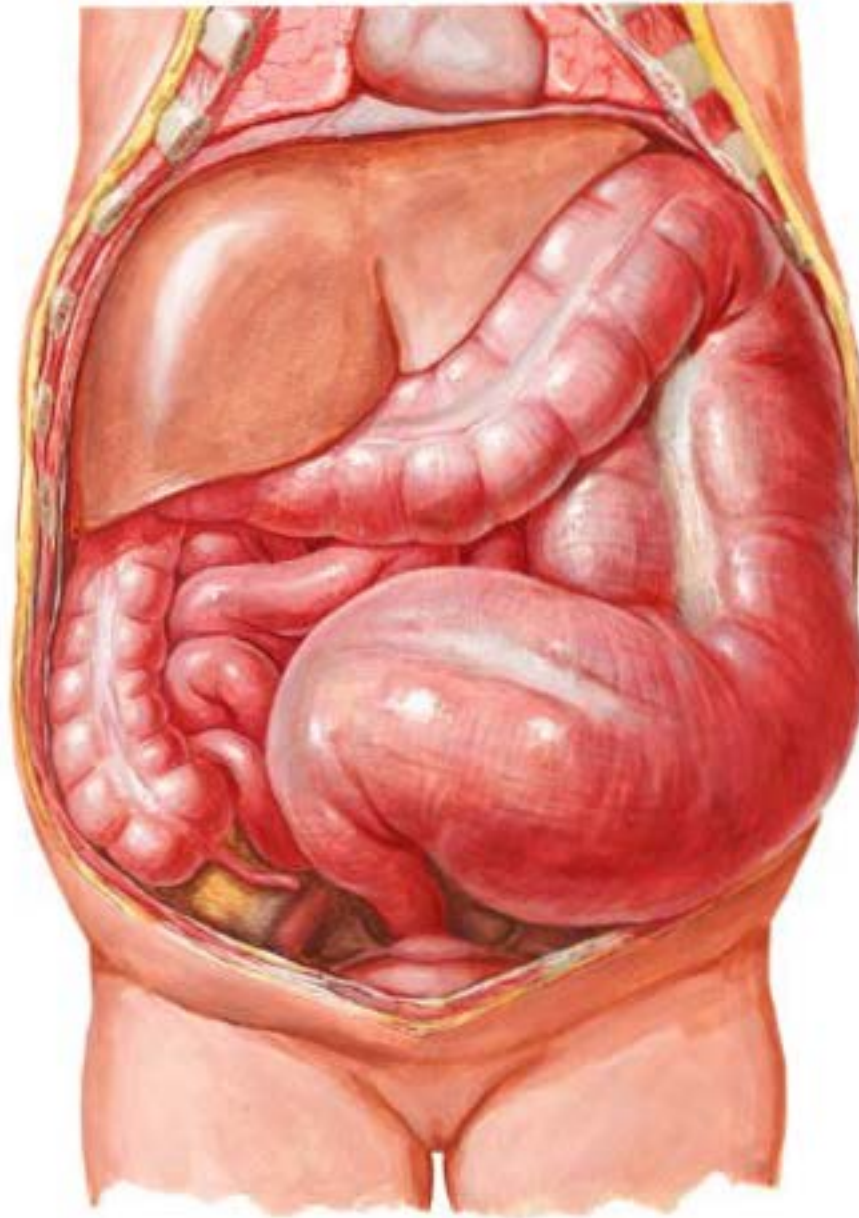
Ends connected by  
cordlike structure





# Congenital Anomalies

## Megacolon (Hirschsprung's Disease)



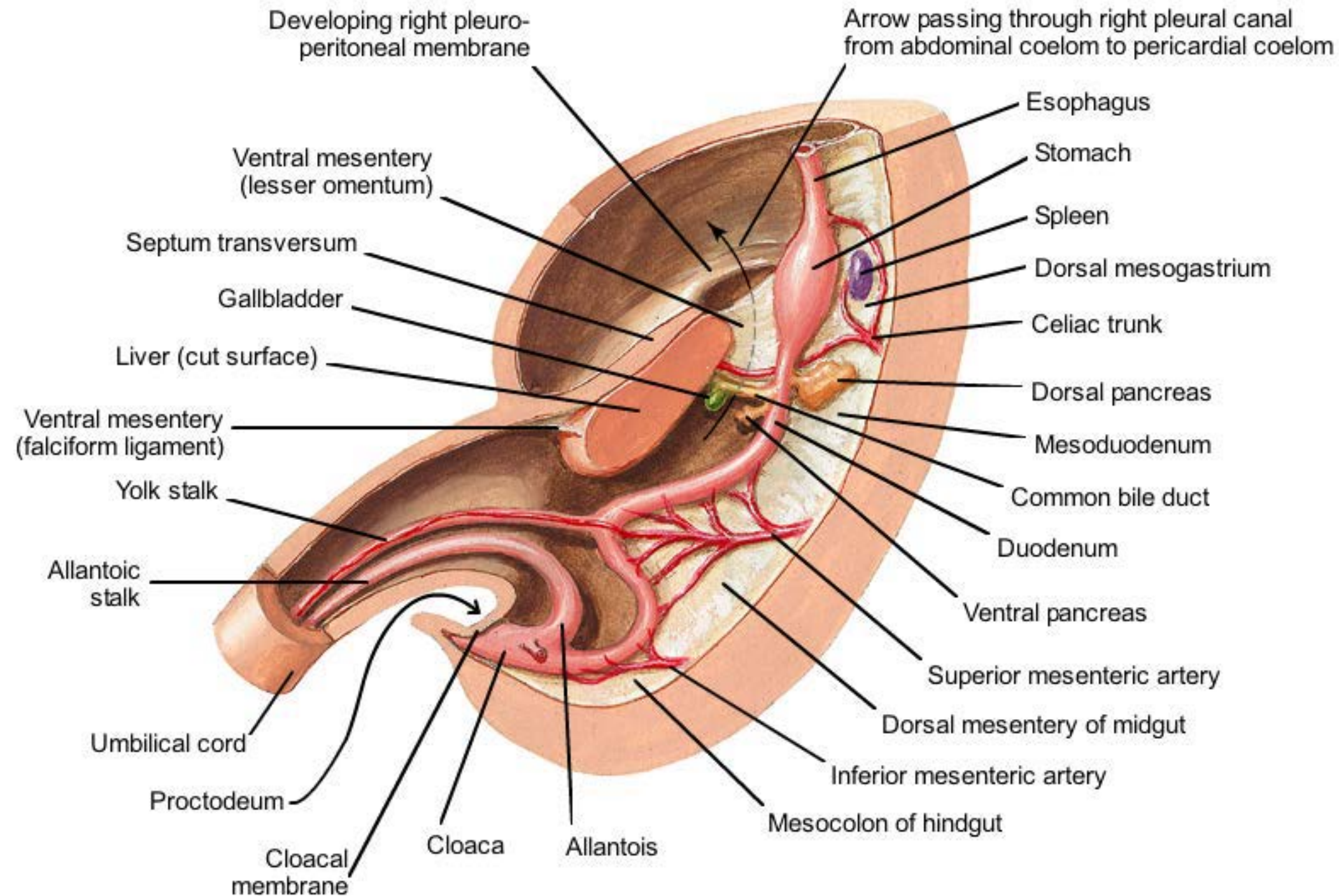
Tremendous distention and hypertrophy of sigmoid and descending colon; moderate involvement of transverse colon; distal constricted segment

Typical abdominal distention



# Summary of Gut Organization

## 5 weeks

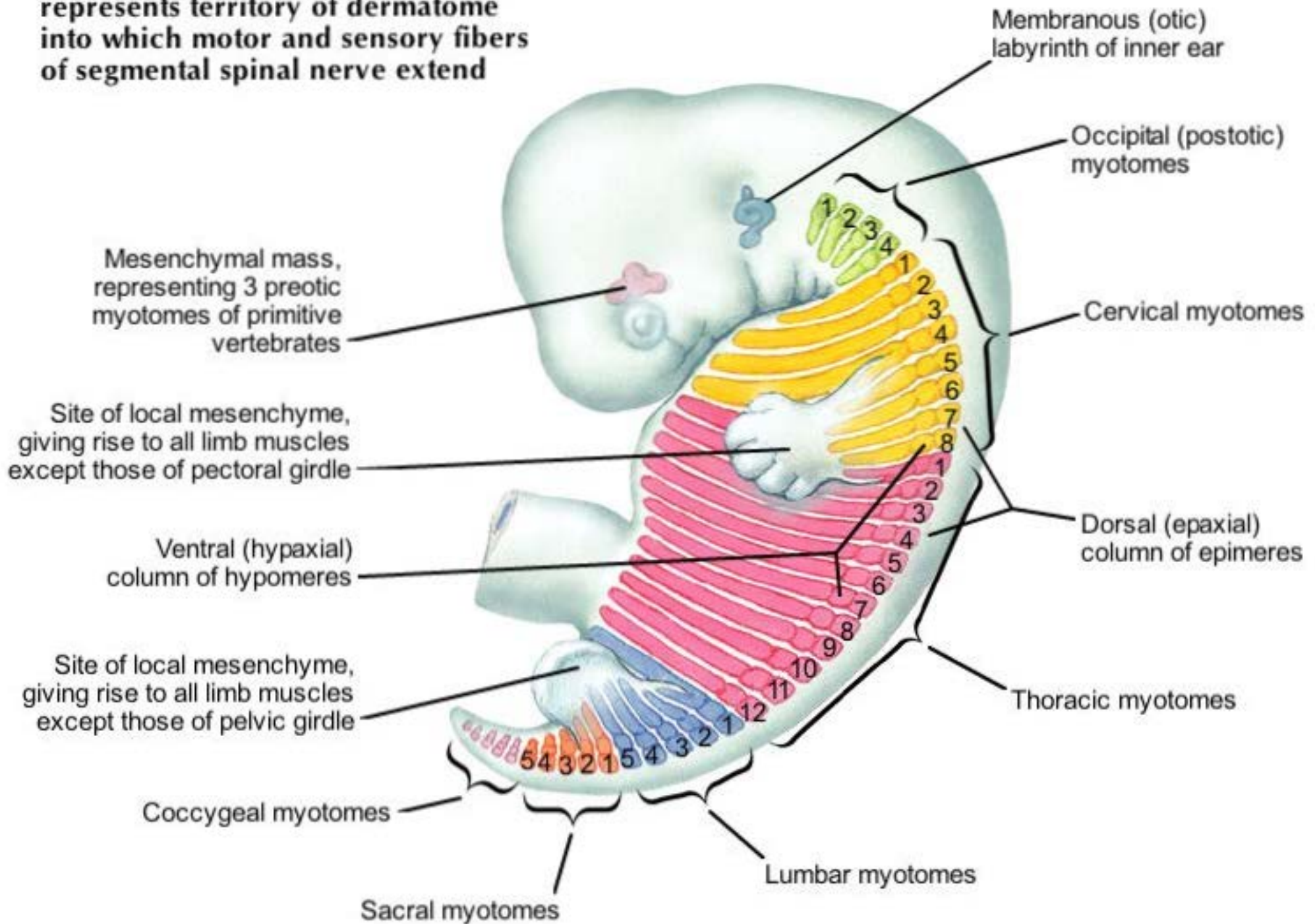




# Development of the Abdominal Wall

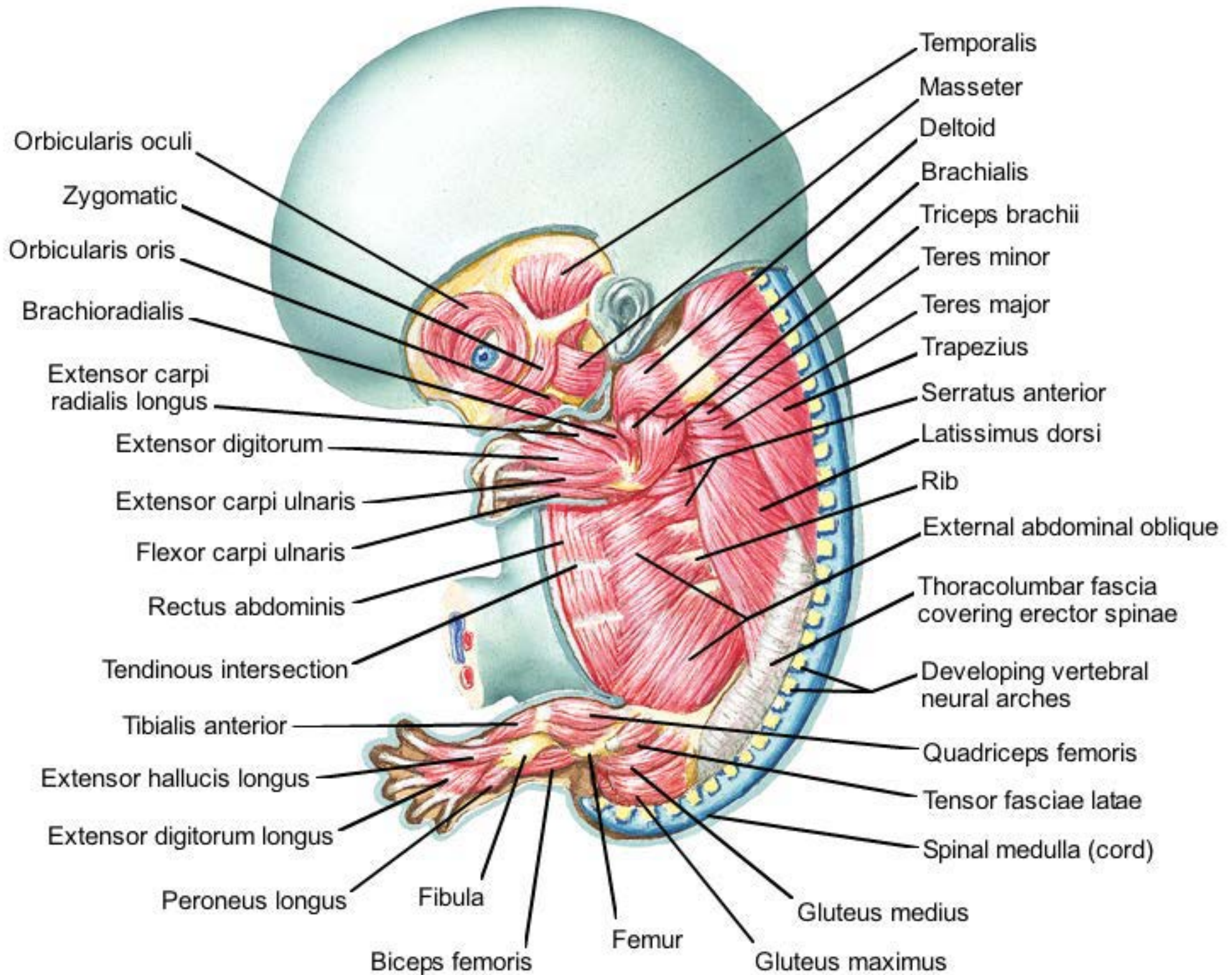
## Segmental distribution of myotomes in fetus of 6 weeks

Region of each trunk myotome also represents territory of dermatome into which motor and sensory fibers of segmental spinal nerve extend



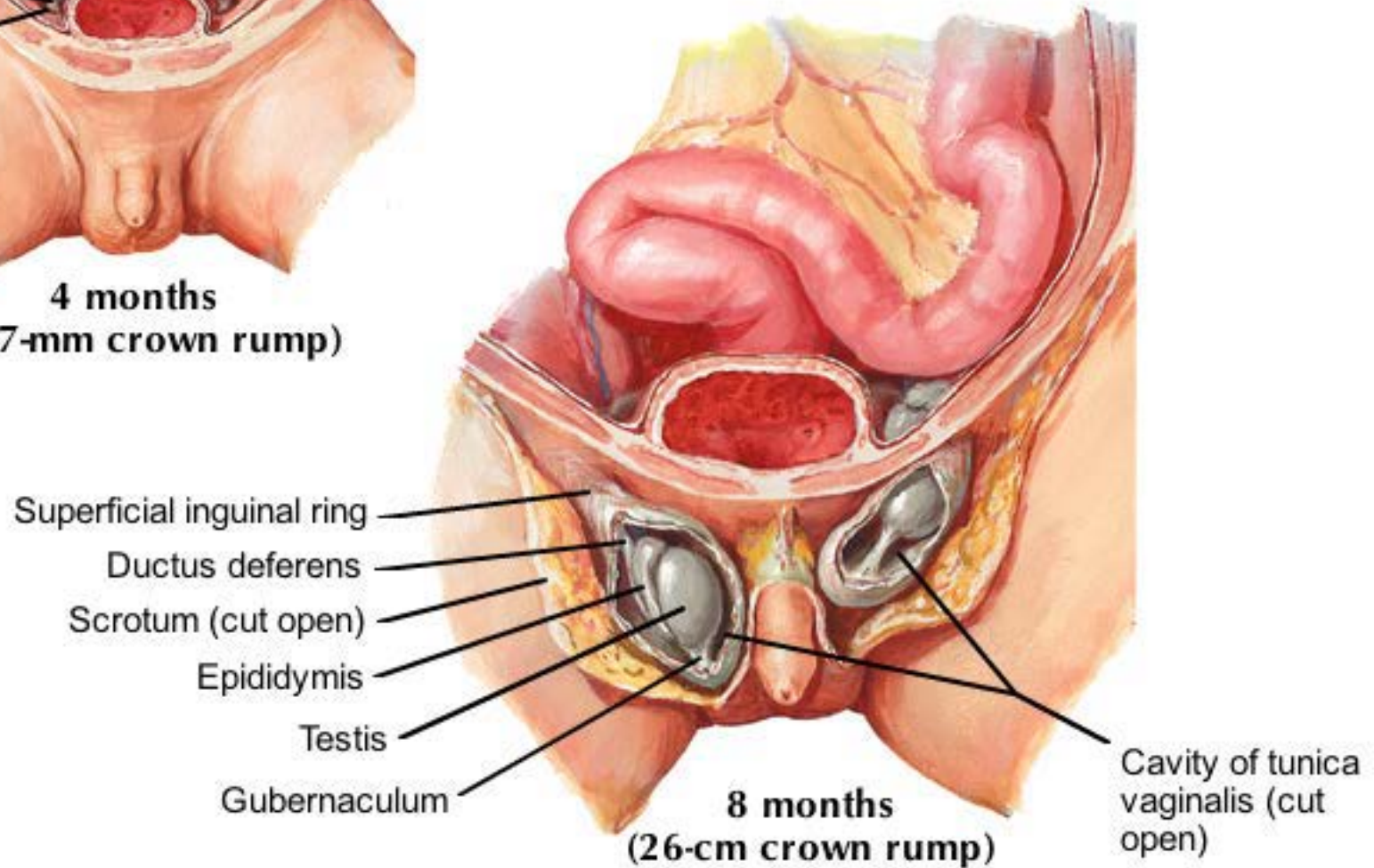
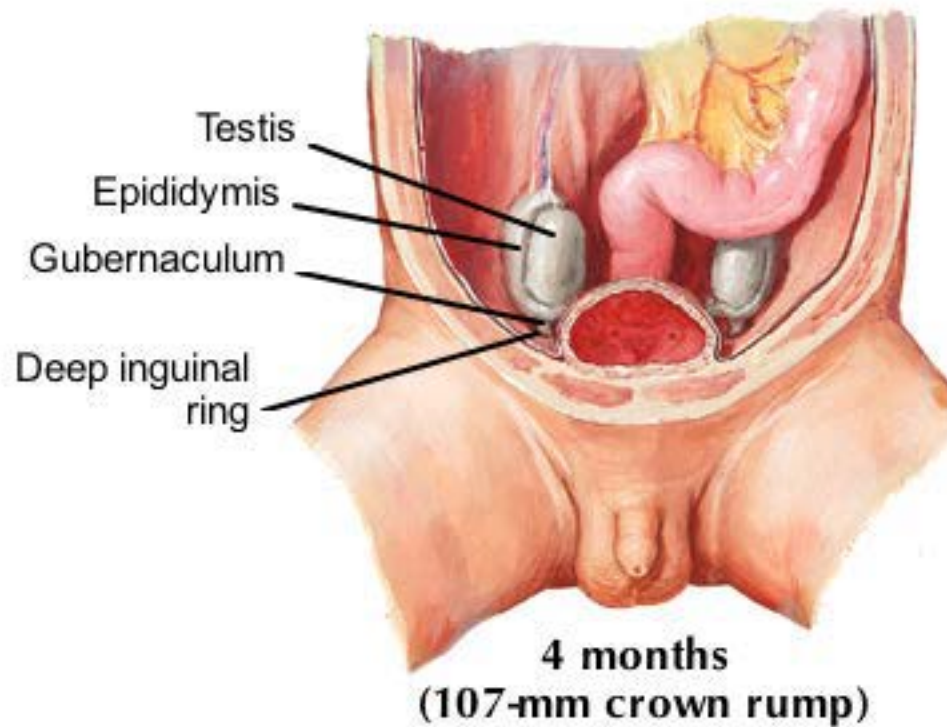
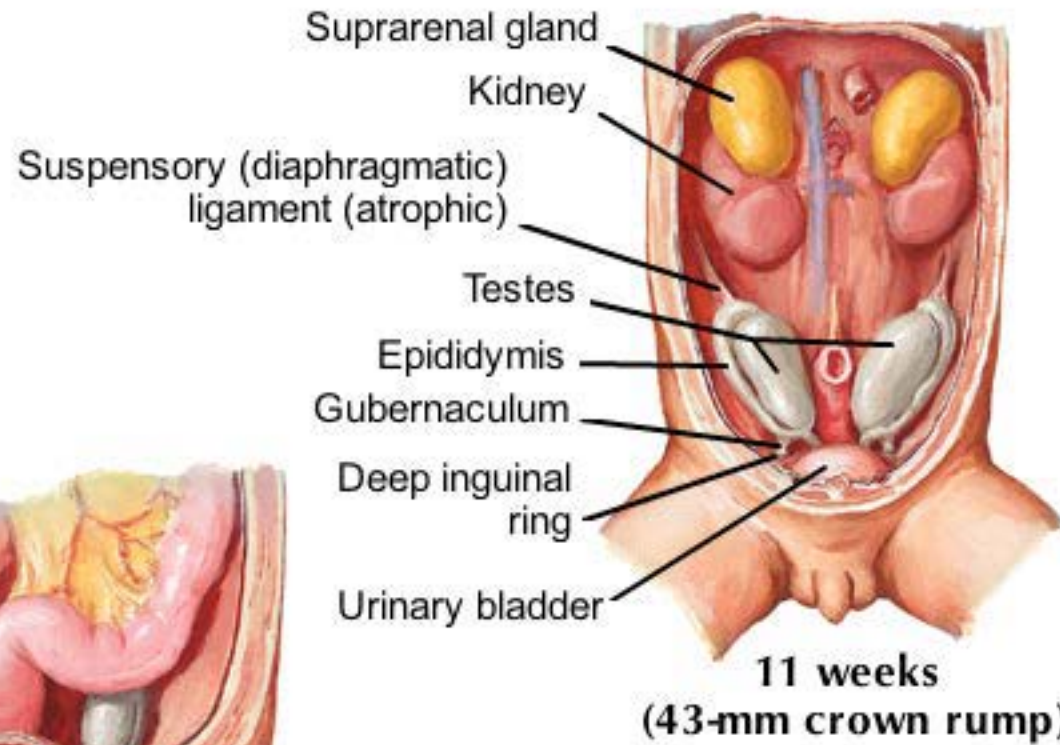
# Development of the Abdominal Wall

## Developing skeletal muscles at 8 weeks (superficial dissection)



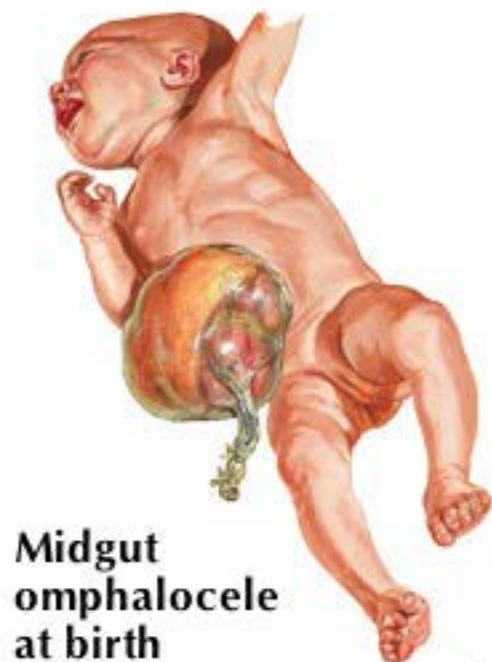


# The Inguinal Region

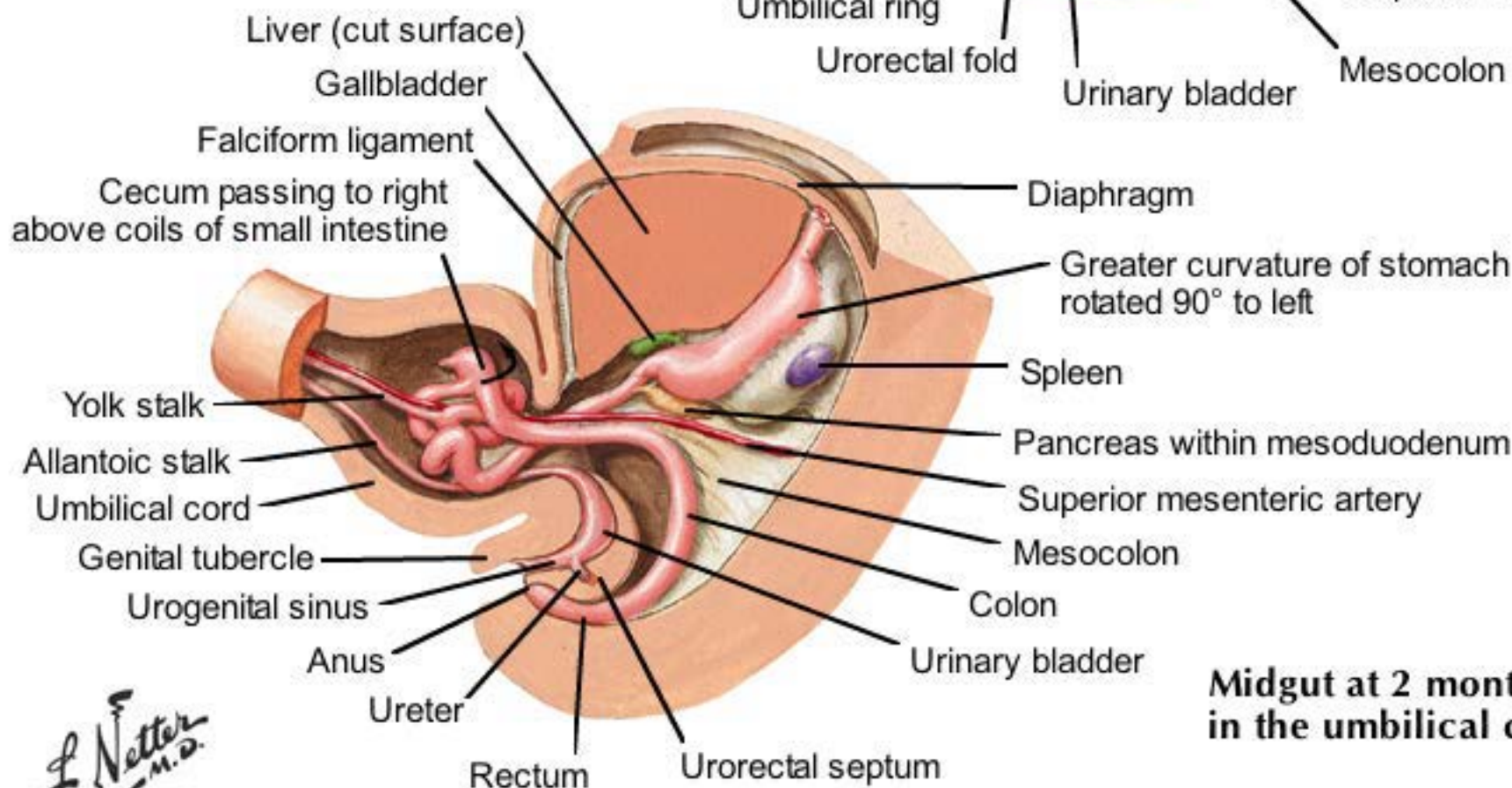
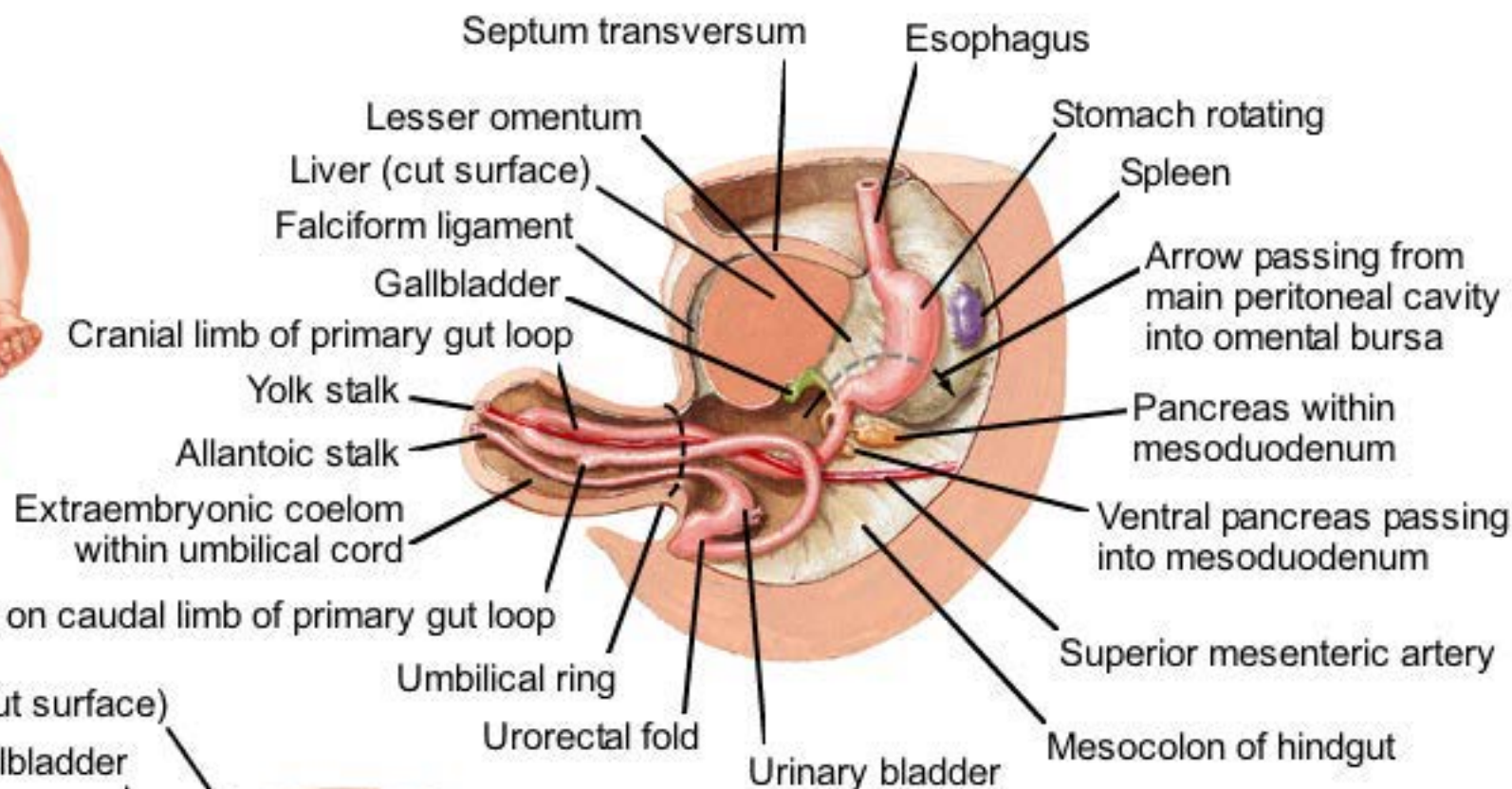




# Umbilical Hernia



**Midgut at 6 weeks in the umbilical cord**

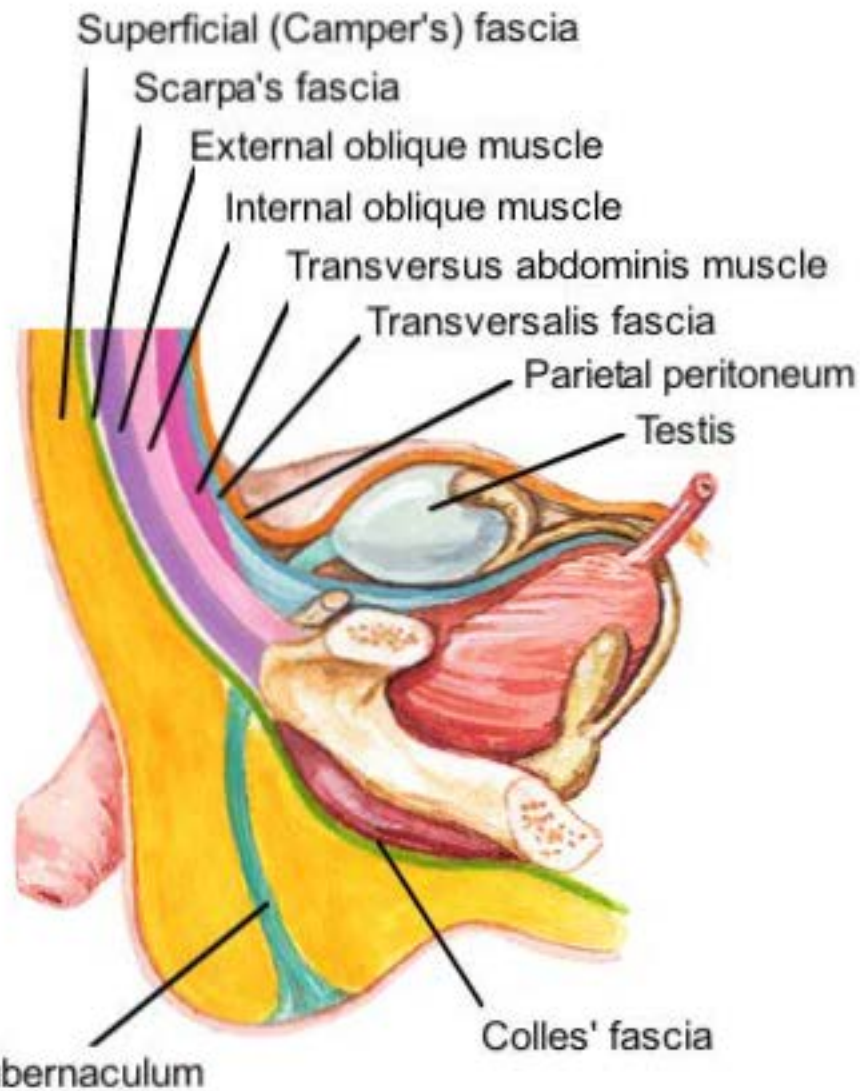


**Midgut at 2 months in the umbilical cord**

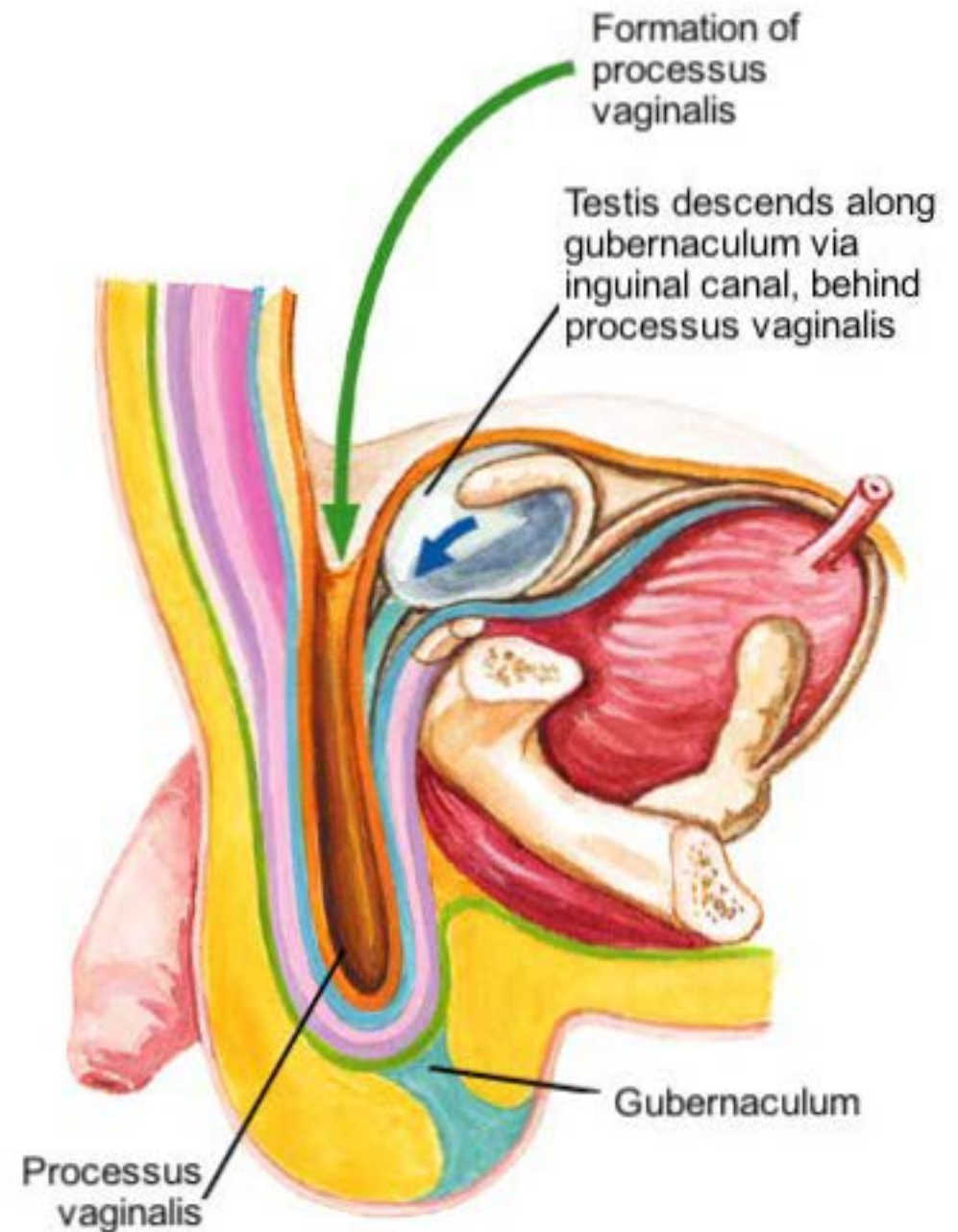


# Anterior Testis Decent

## Testicular descent

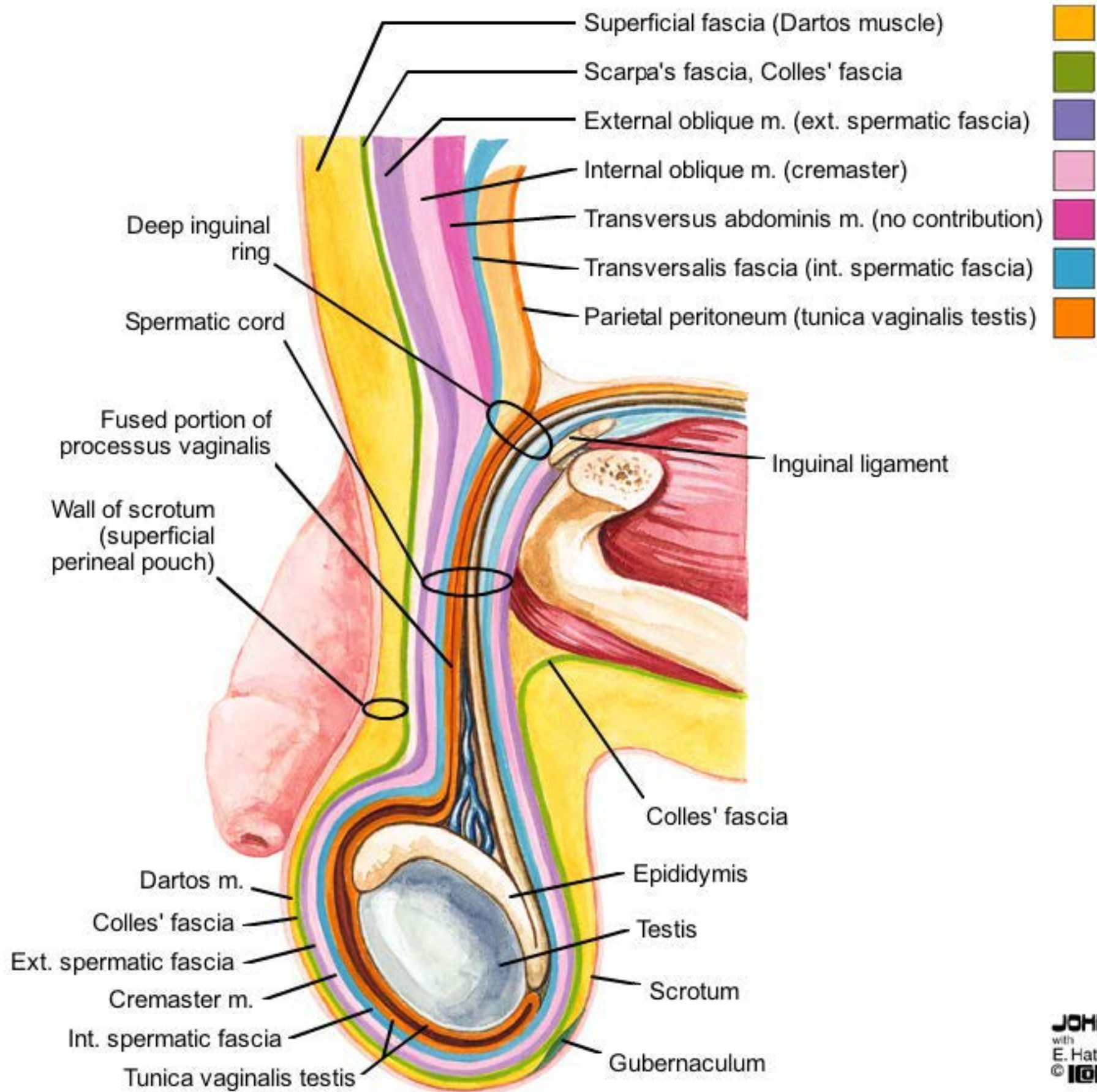


Abdominal position of testis (between parietal peritoneum and transversalis fascia)



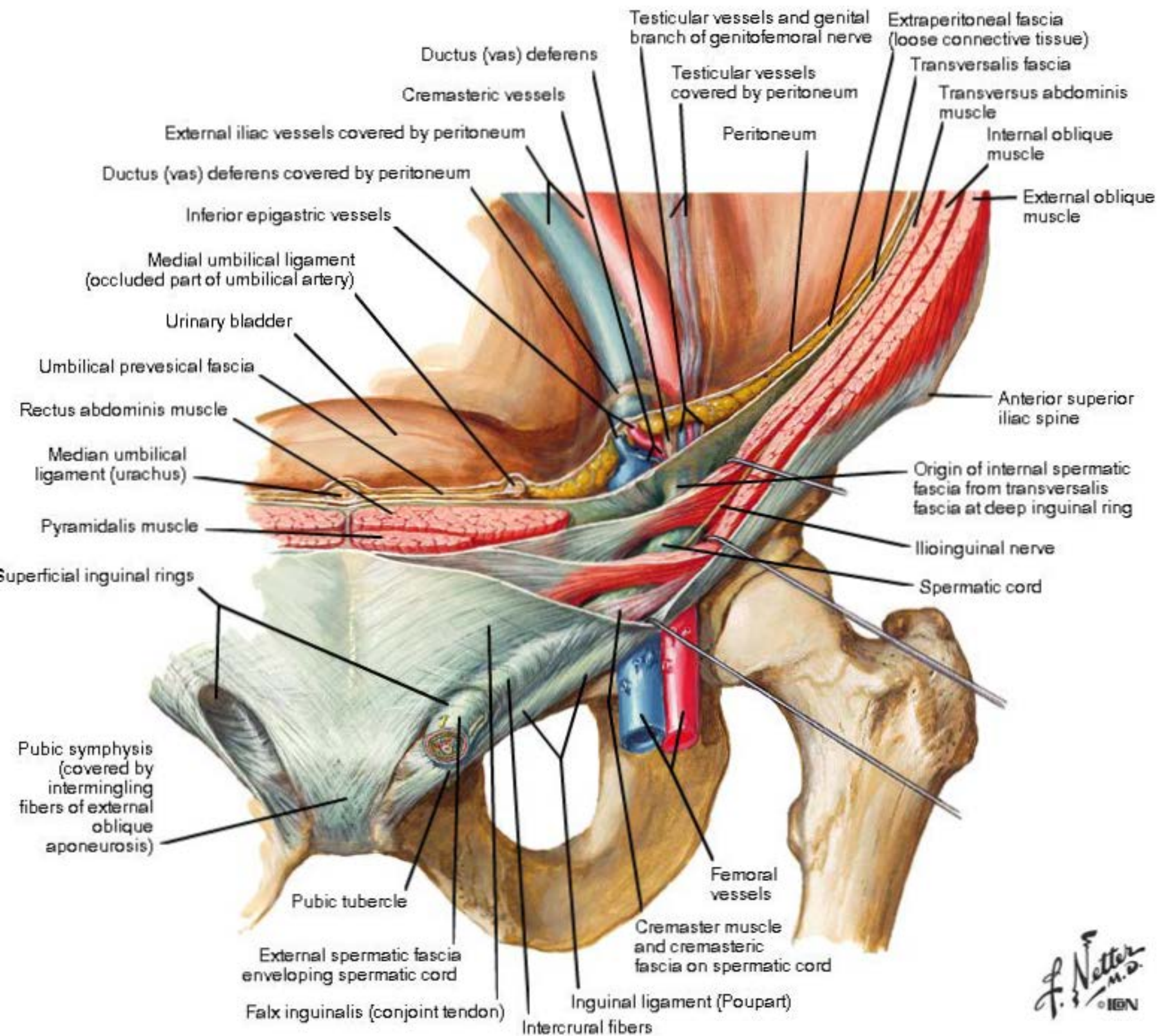
# Anterior Testis Descent

## Adult configuration



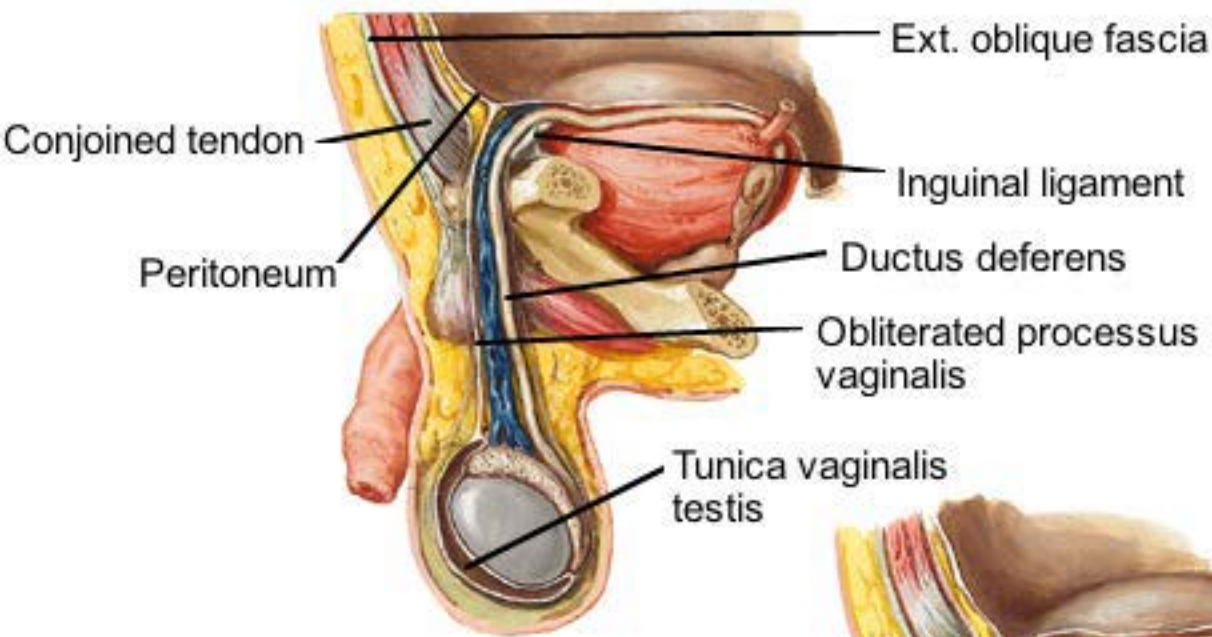


# The Adult Inguinal Region

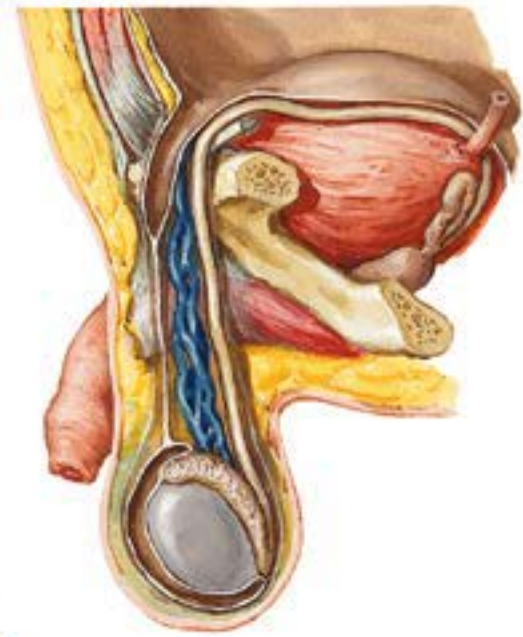




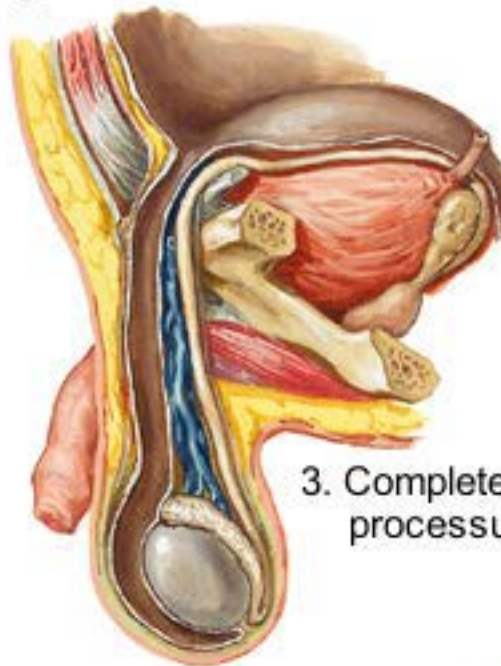
# Anomalies of the Processus Vaginalis



1. Normally obliterated processus vaginalis

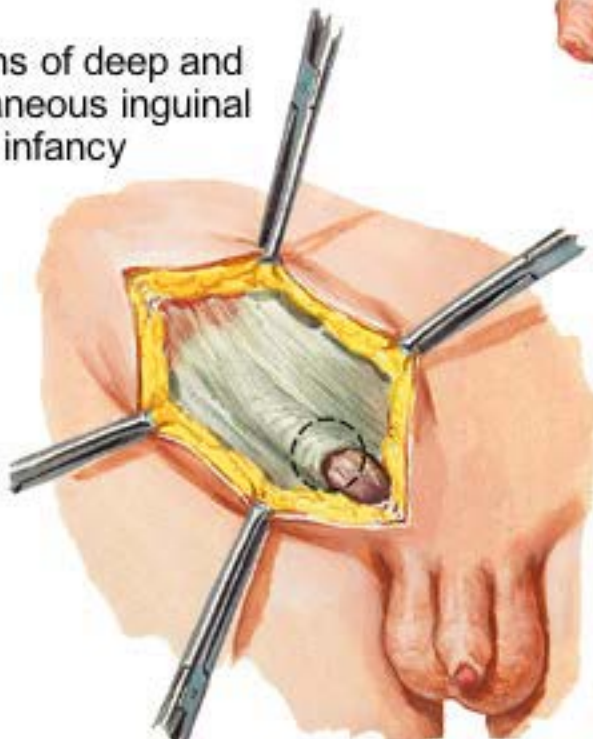


2. Partially patent processus vaginalis (small congenital hernia)

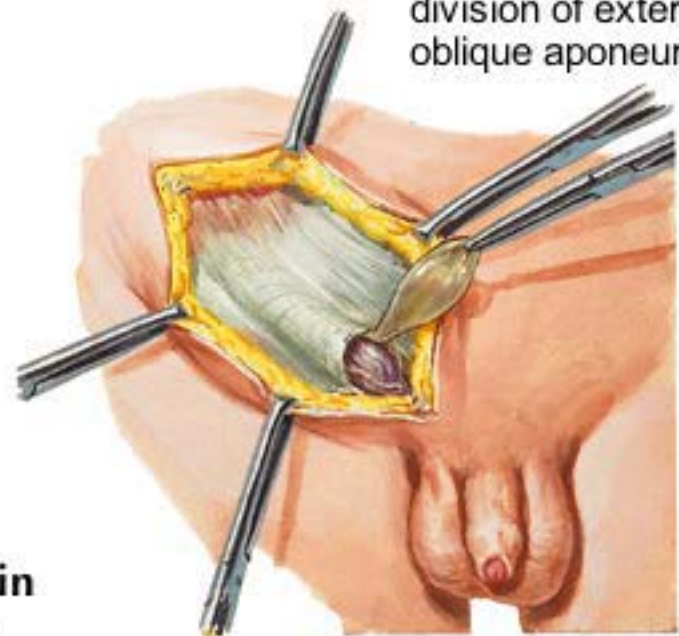


3. Completely patent processus vaginalis

Relations of deep and subcutaneous inguinal rings in infancy



Sac liberated without division of external oblique aponeurosis



Hernia in infancy



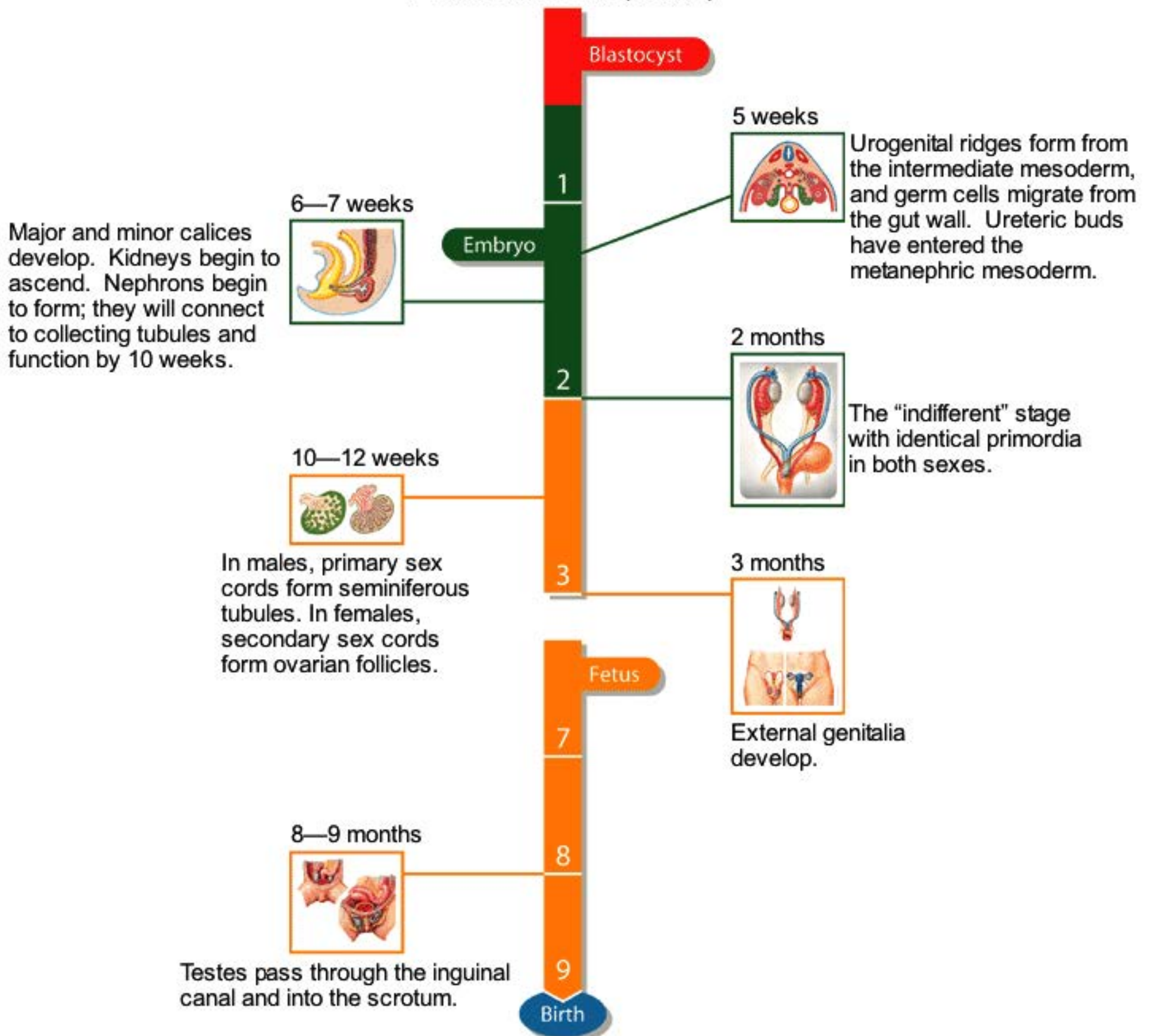
# Organization of the Abdominal GI Tract

## ORGANIZATION OF THE ABDOMINAL GI TRACT

	Foregut	Midgut	Hindgut
<b>Organs</b>	Stomach Liver Gallbladder Pancreas Spleen 1st half of duodenum	2nd half of duodenum Jejunum and ileum Cecum Ascending colon $\frac{2}{3}$ of transverse colon	Left $\frac{1}{3}$ of transverse colon Descending colon Sigmoid colon Rectum
<b>Arteries</b>	Celiac trunk: Splenic artery Left gastric Common hepatic	Superior mesenteric: Ileocolic Right colic Middle colic	Inferior mesenteric: Left colic Sigmoid branches Superior rectal
<b>Ventral mesentery</b>	Lesser omentum Falciform ligament Coronary/triangular ligaments	None	None
<b>Dorsal mesentery</b>	Gastrosplenic ligament Splenorenal ligament Gastrocolic ligament Greater omentum	Mesointestine Mesoappendix Transverse mesocolon	Sigmoid mesocolon
<b>Motor nerve supply</b>	Vagus	Vagus	Pelvic splanchnic nerves

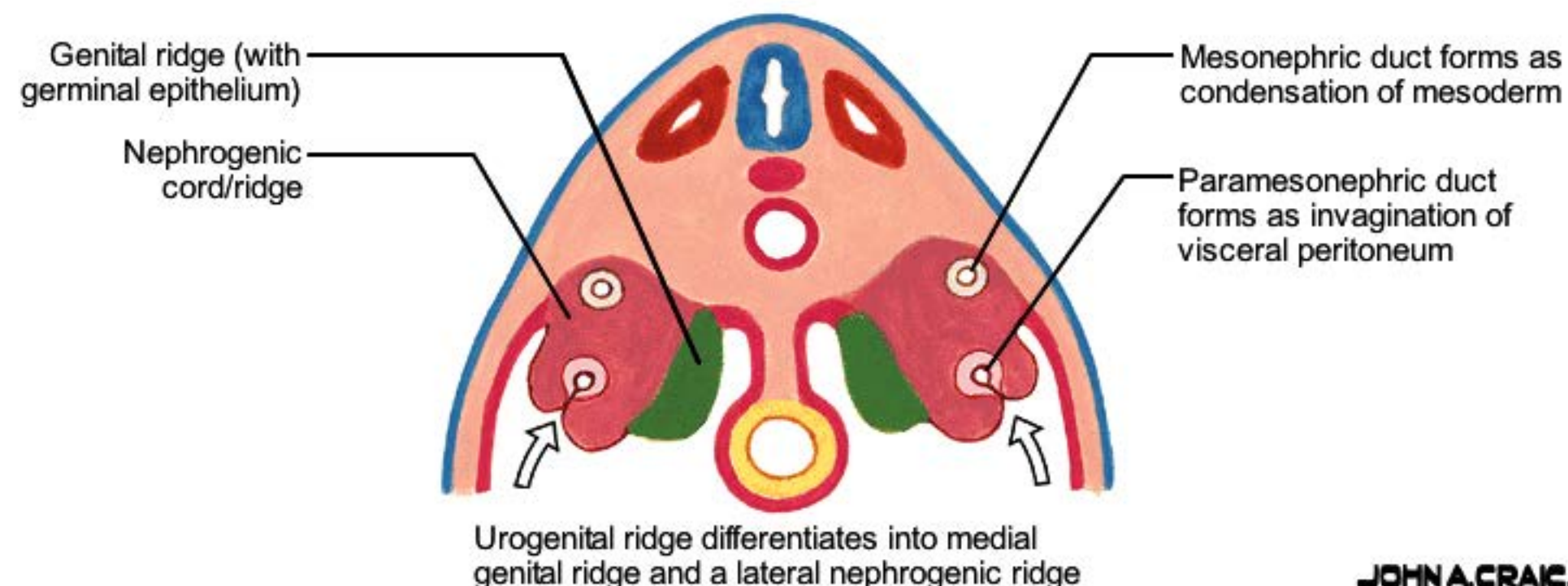
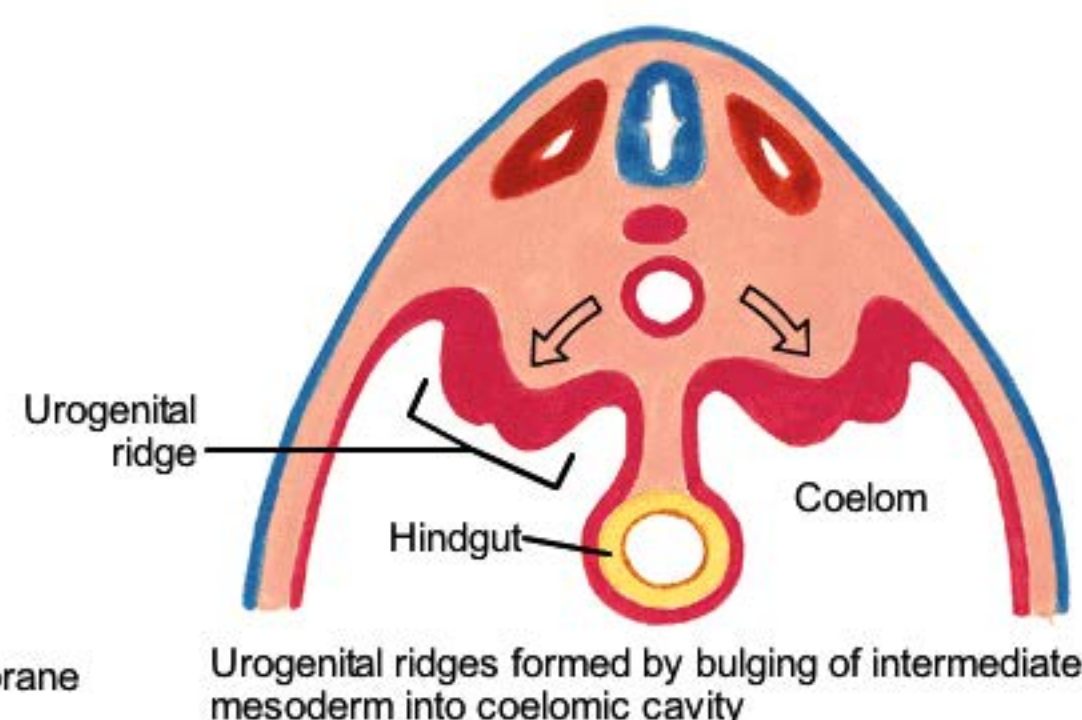
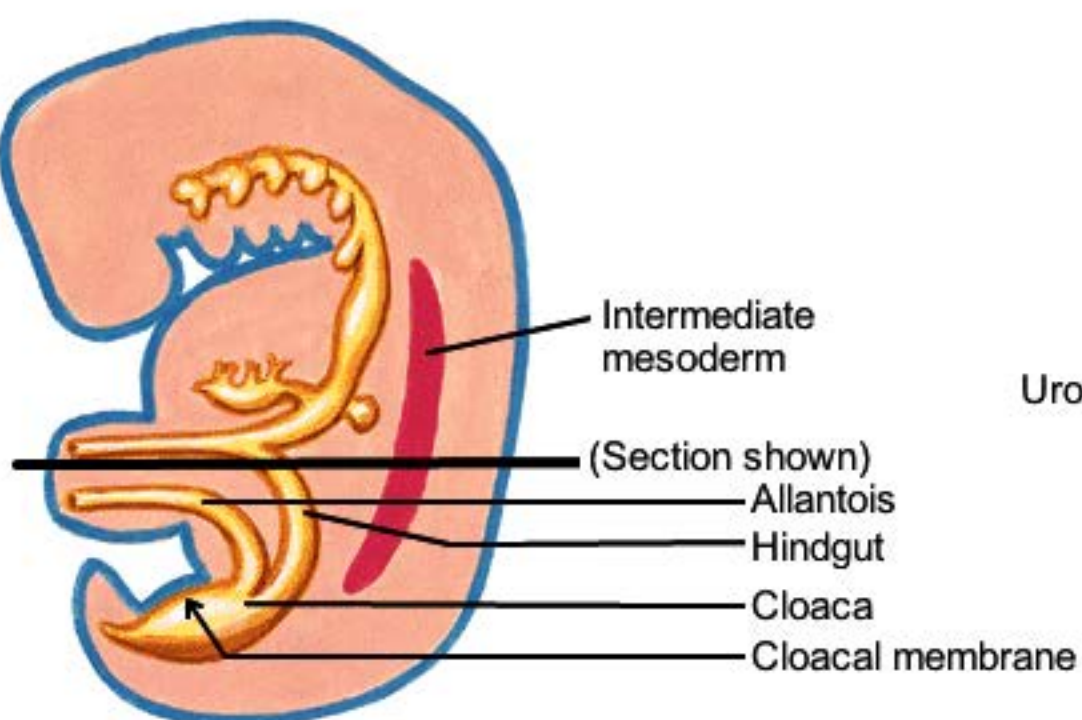
# THE UROGENITAL SYSTEM TIMELINE

Prenatal Time Scale (Months)

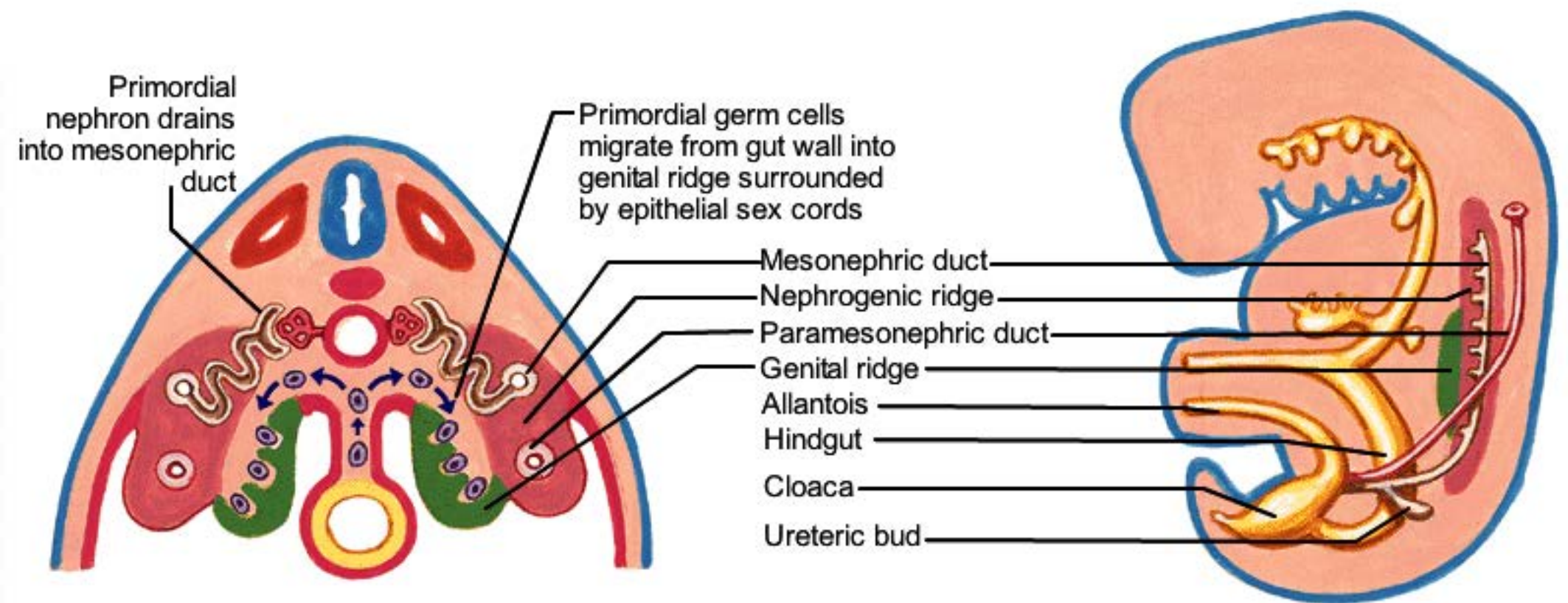




# Early Primordia



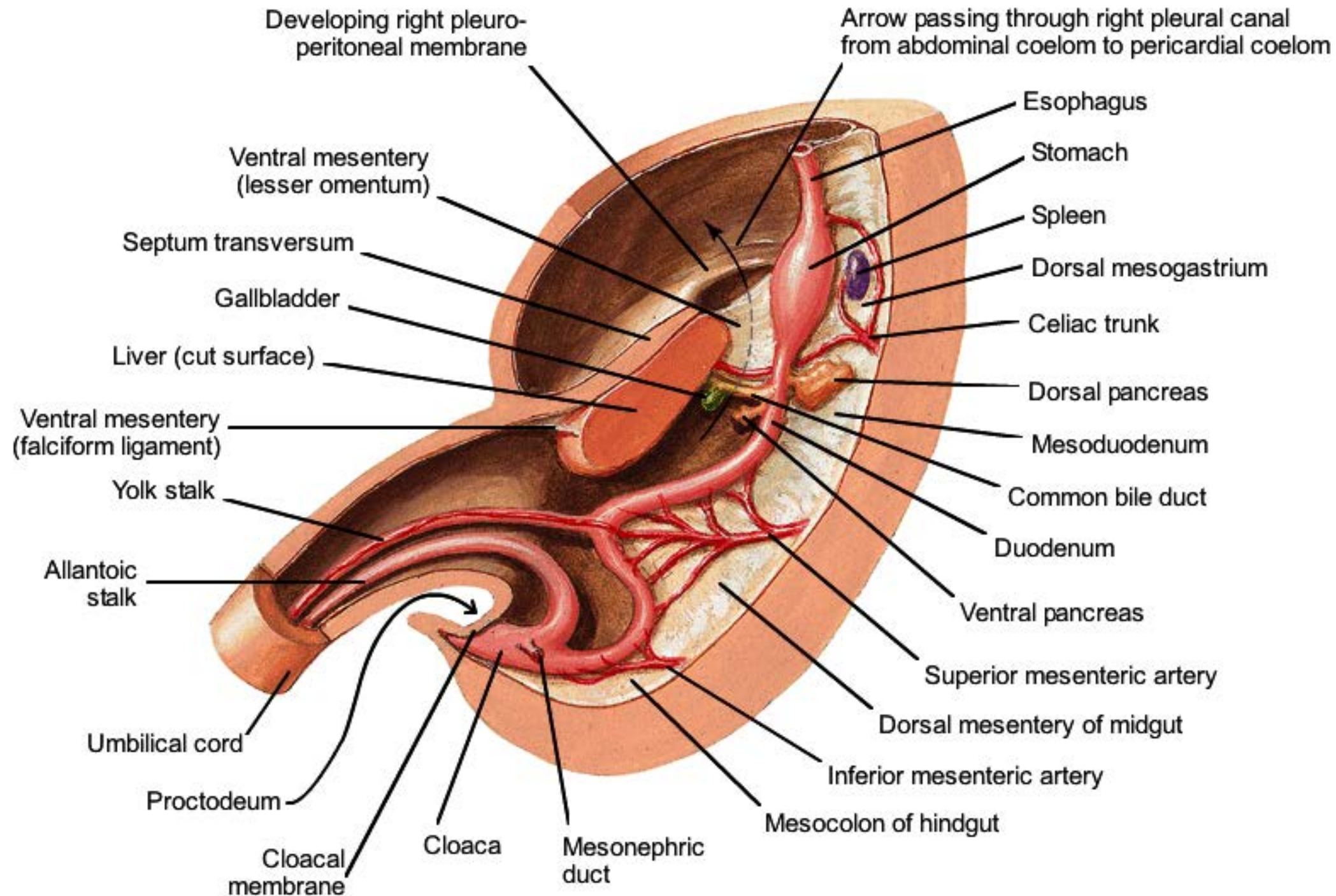
# Early Primordia





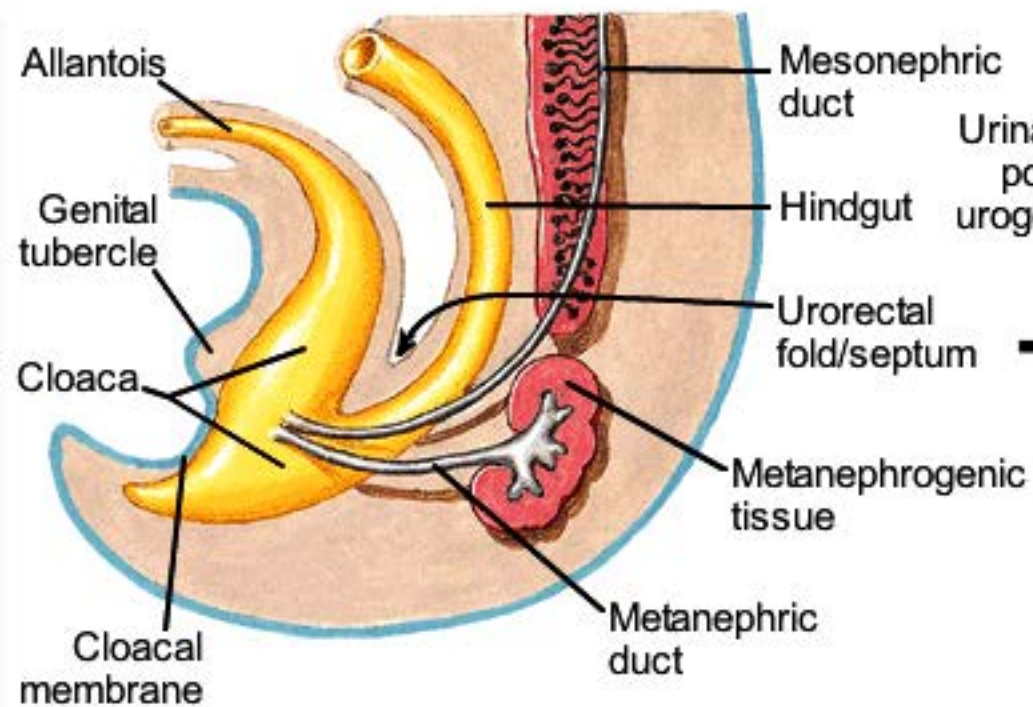
# Division of the Cloaca

## Abdominal foregut, midgut, and hindgut at 5 weeks

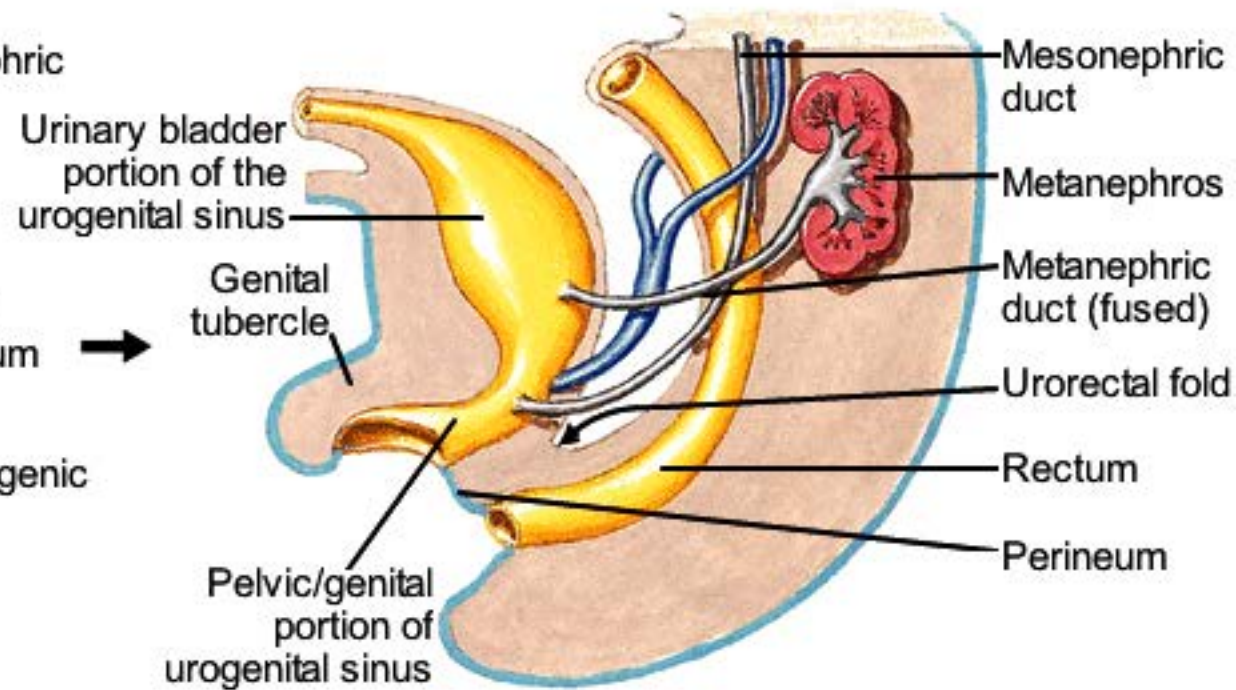


# Division of the Cloaca

Division of the cloaca by the urorectal septum



Urogenital sinus and rectum





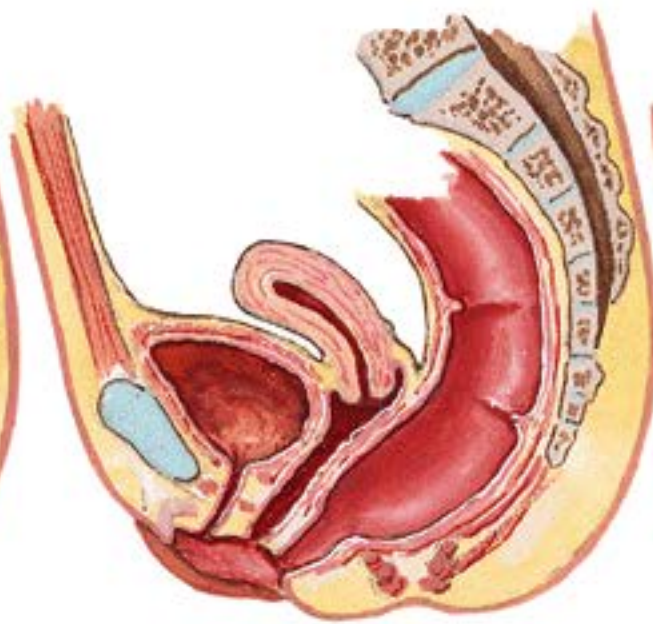
# Congenital Cloacal Anomalies

Fistulas resulting from the incomplete division of the cloaca

In females



Rectoperineal

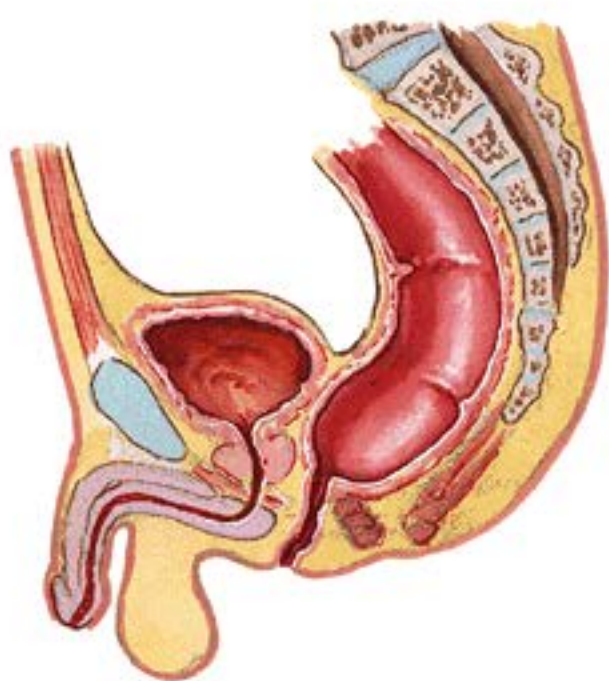


Rectovestibular

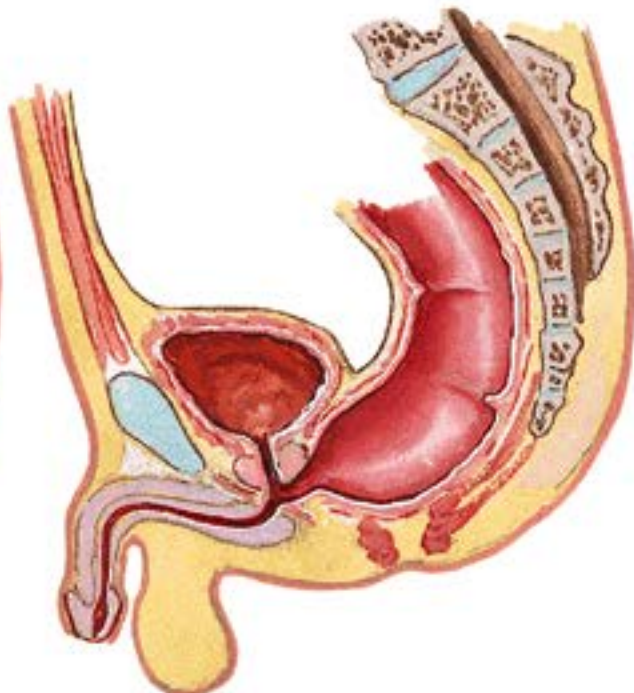


Rectovaginal

In males



Rectoperineal



Rectourethral

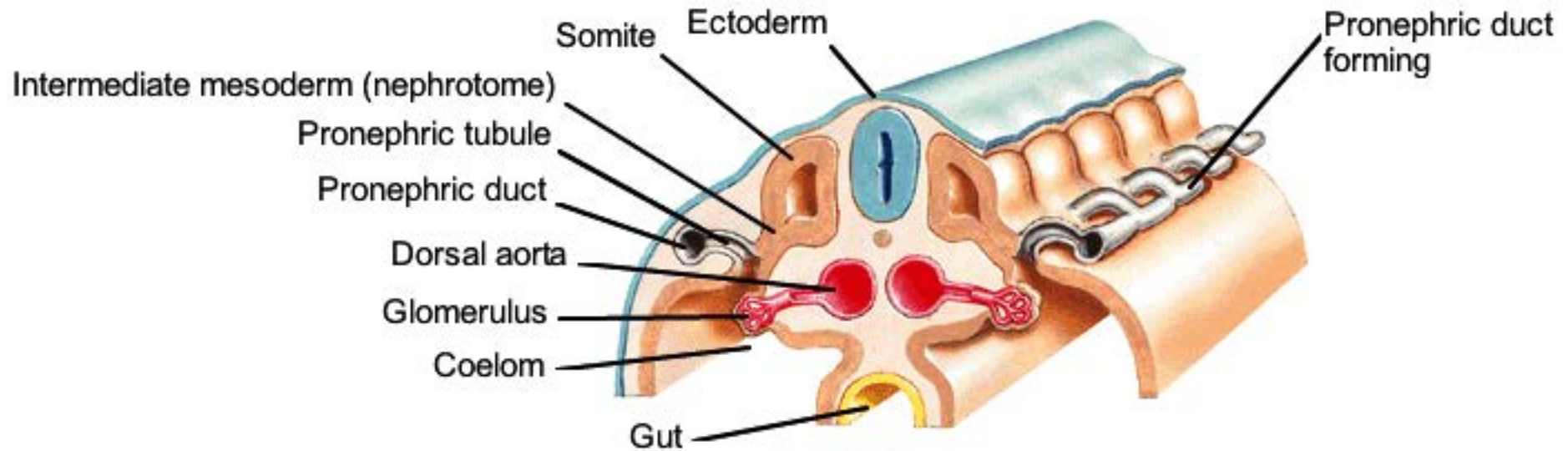


Rectovesical

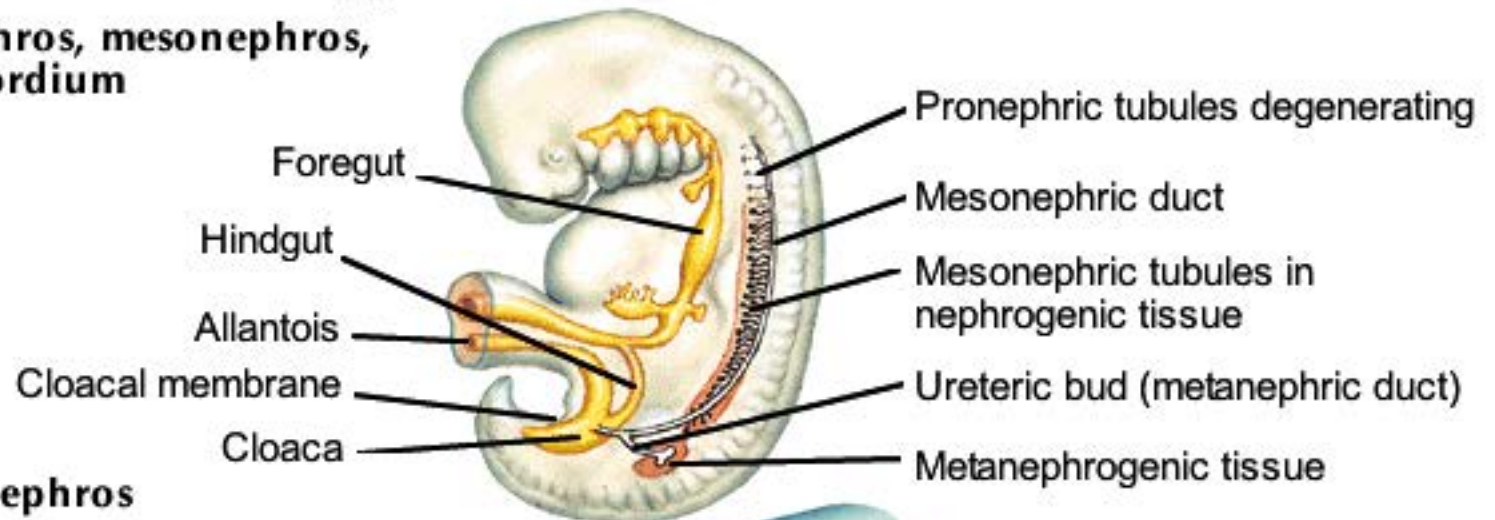


# Pronephros, Mesonephros, and Metanephros

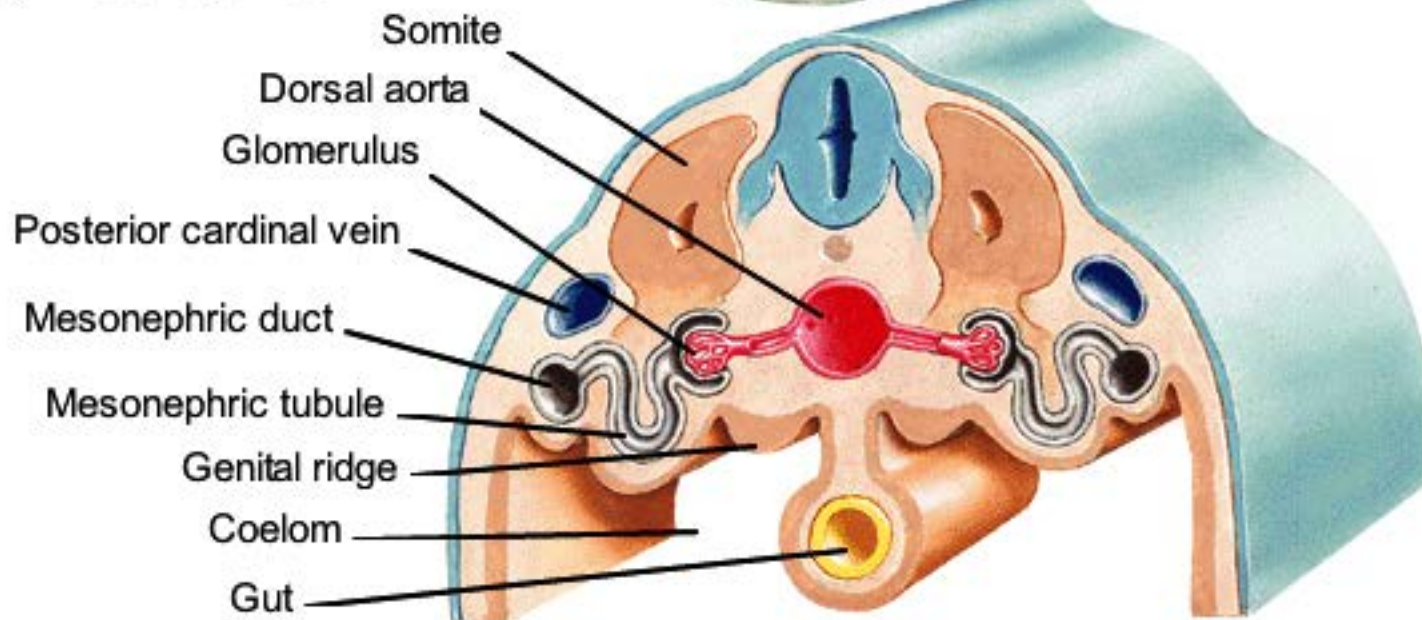
## Section through pronephros



## Topography of pronephros, mesonephros, and metanephric primordium

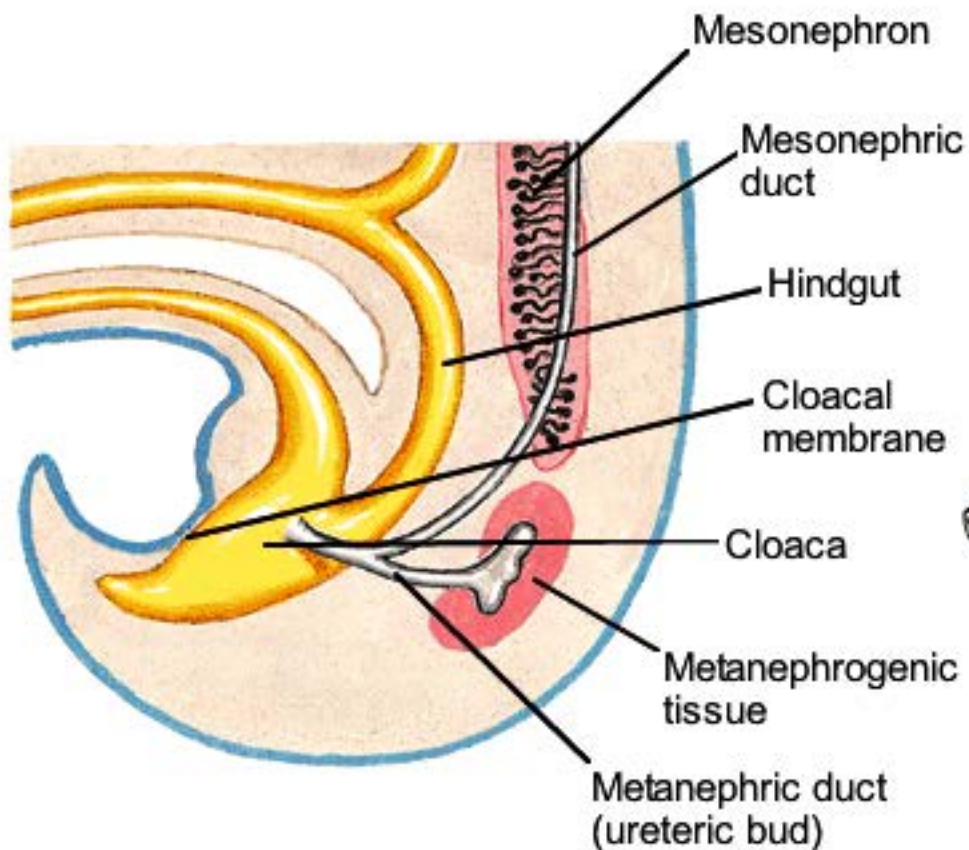


## Section through mesonephros

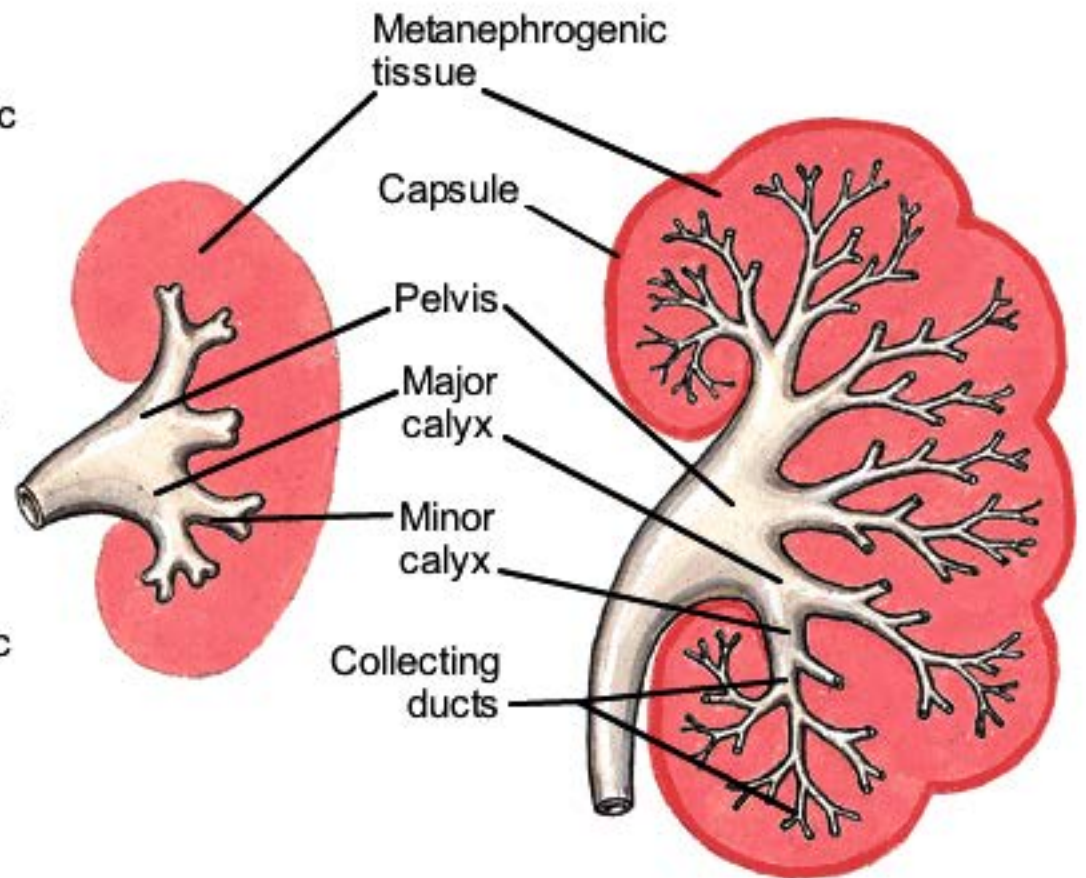




# Development of the Metanephros



A. The metanephric duct (ureteric bud) has grown out from the mesonephric duct, close to termination of latter in cloaca, and has invaded the metanephrogenic mesoderm.

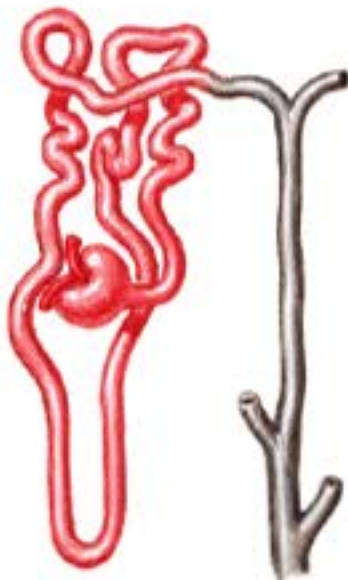


B. Within the metanephrogenic tissue, the ureteric bud expands to form a pelvis, which branches into calyces, and these, in turn, bud into successive generations of collecting ducts.

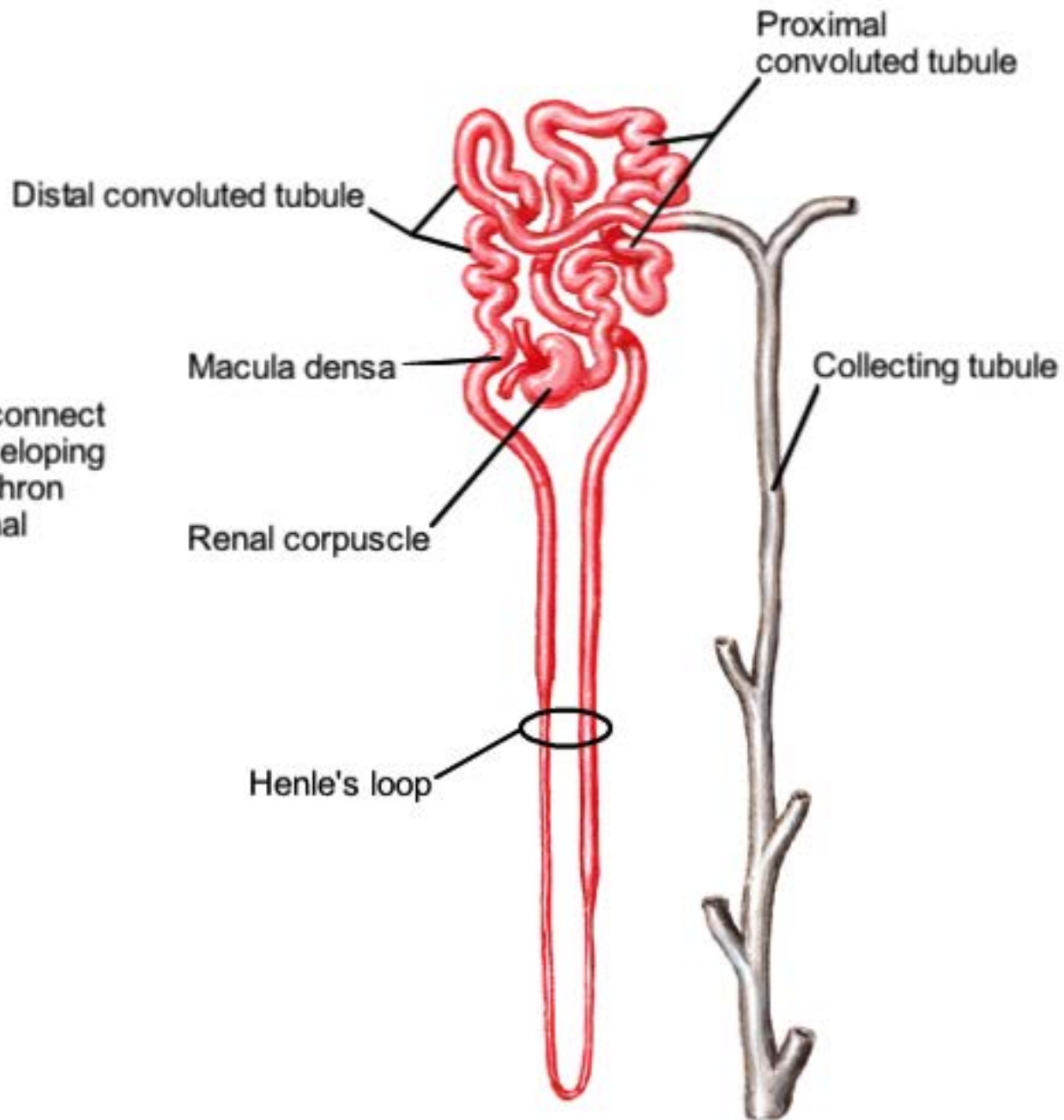
# Development of the Metanephros



C. The distal ends of the collecting ducts connect with the tubule system of the nephron developing from the metanephric mesoderm. The nephron extends from the collecting duct to the renal corpuscle.



D. The tubule lengthens, coils, and begins to dip down toward the renal pelvis, as Henle's loop; one area of the tubule remains close to the glomerular mouth, as the future macula densa.



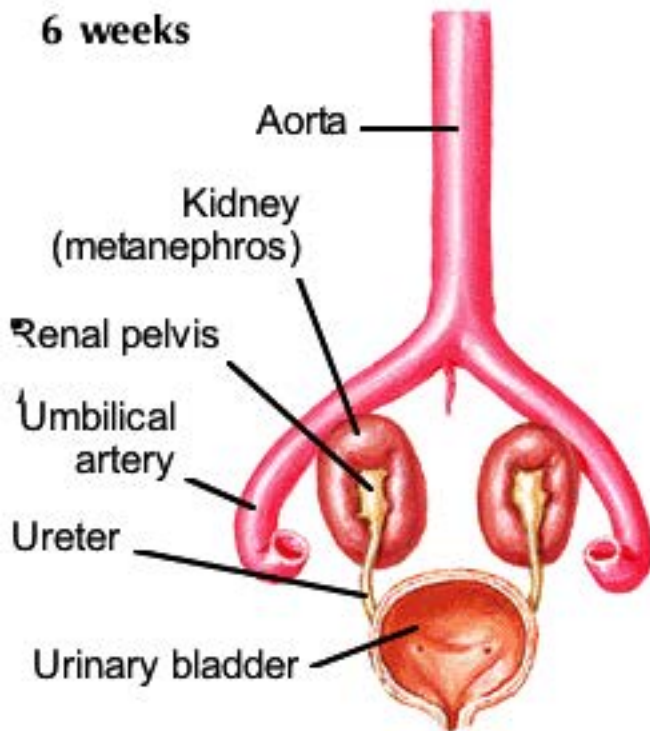
E. The loop elongates; renal corpuscle, proximal tubule, Henle's loop, distal tubule, and macula densa of mature nephron are thus derived from metanephrogenic mesoderm and collecting tubules from the metanephric duct.



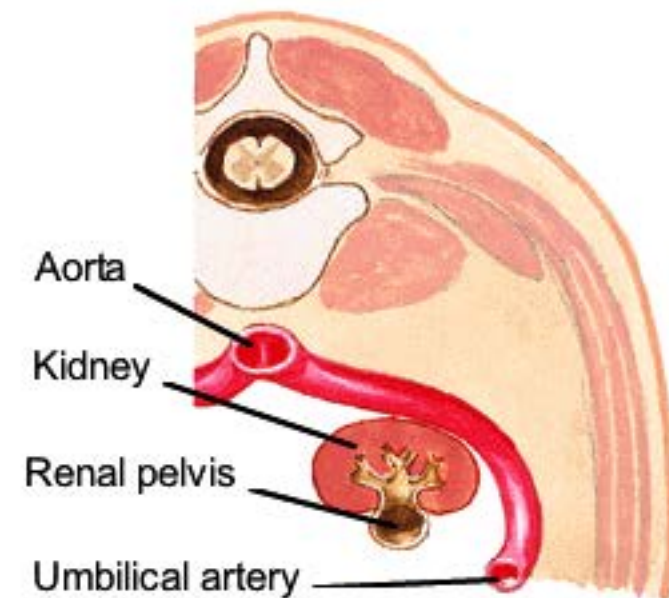
# Ascent and Rotation of the Metanephric Kidneys

Apparent "ascent and rotation" of the kidneys in embryological development

6 weeks

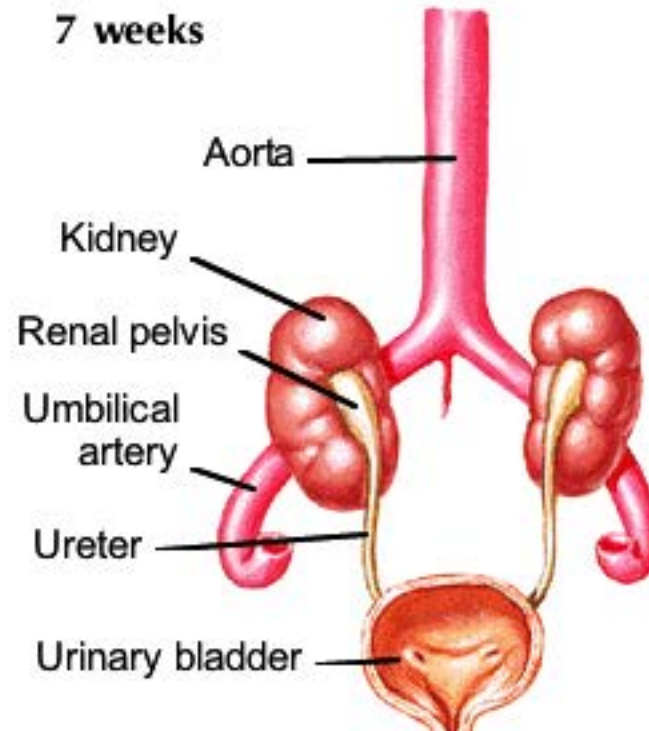


Frontal view

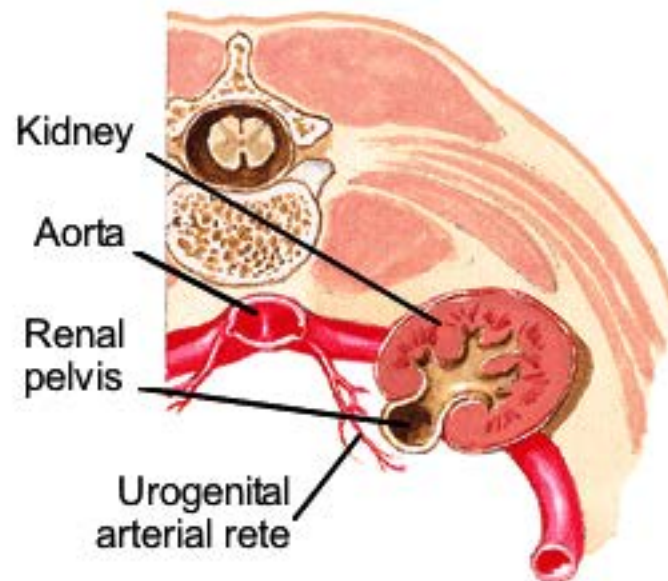


Cross section

7 weeks

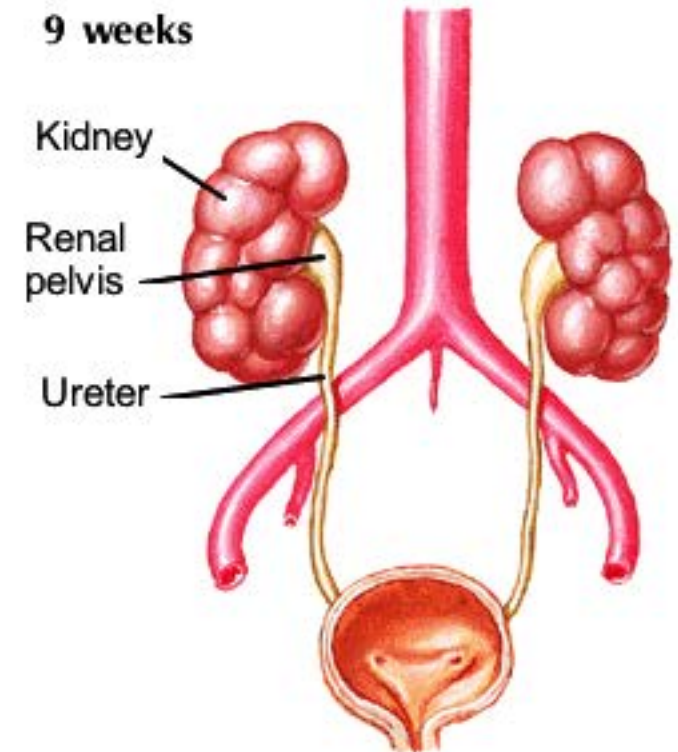


Frontal view

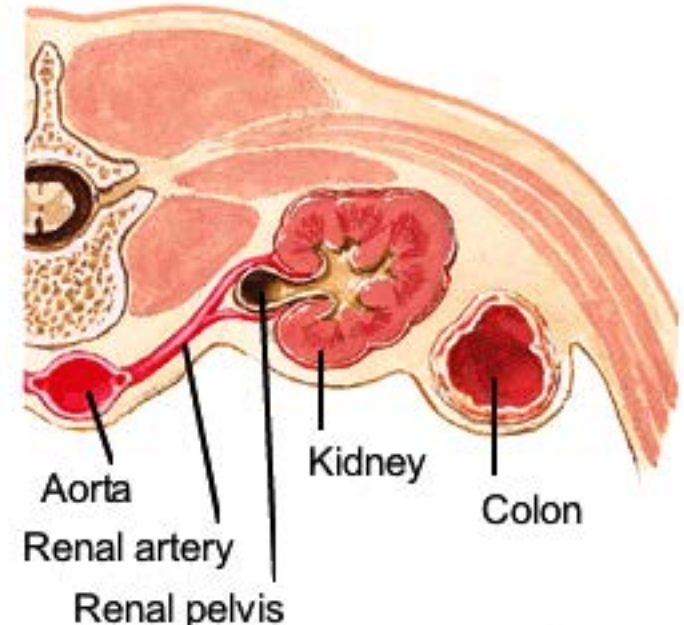


Cross section

9 weeks



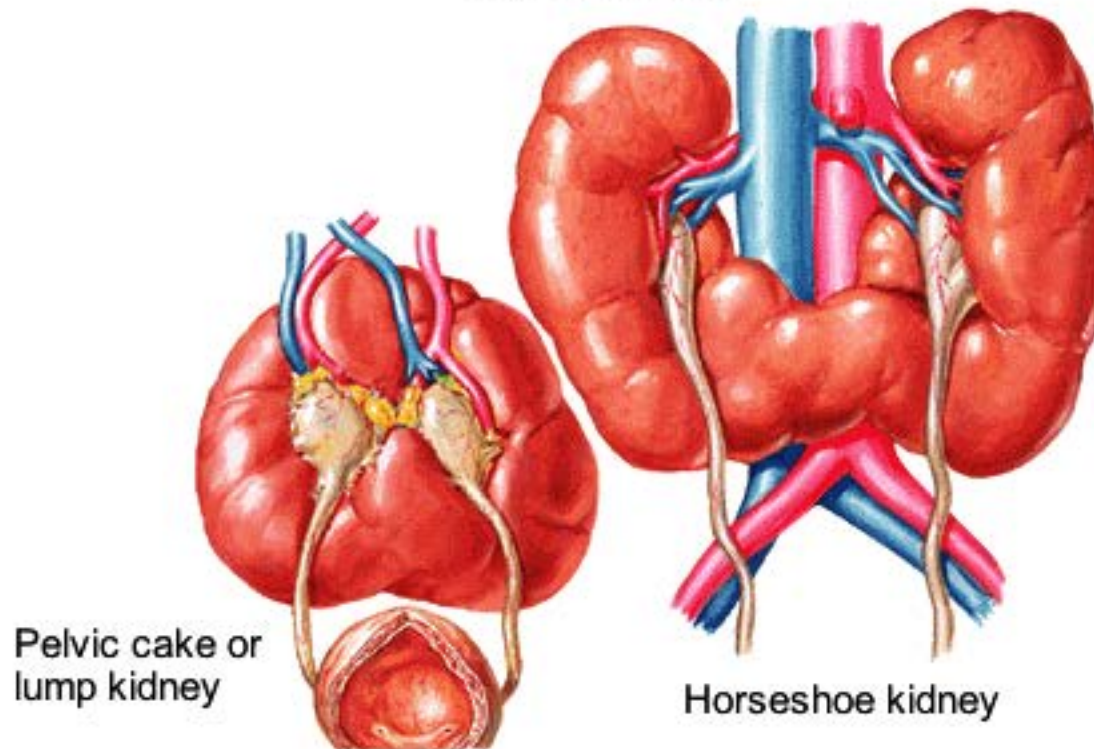
Frontal view



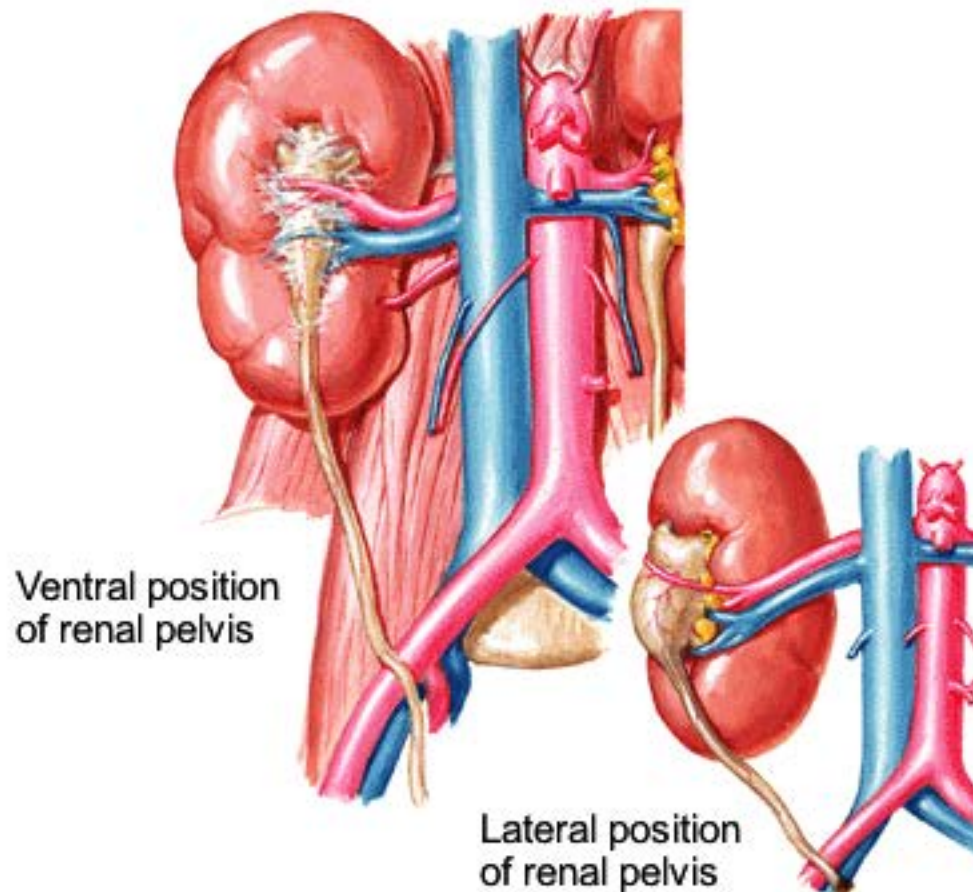
Cross section

# Kidney Rotation and Migration Anomalies

## Renal fusion



## Anomalies of renal rotation

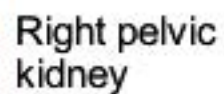




### Ectopia of the kidney

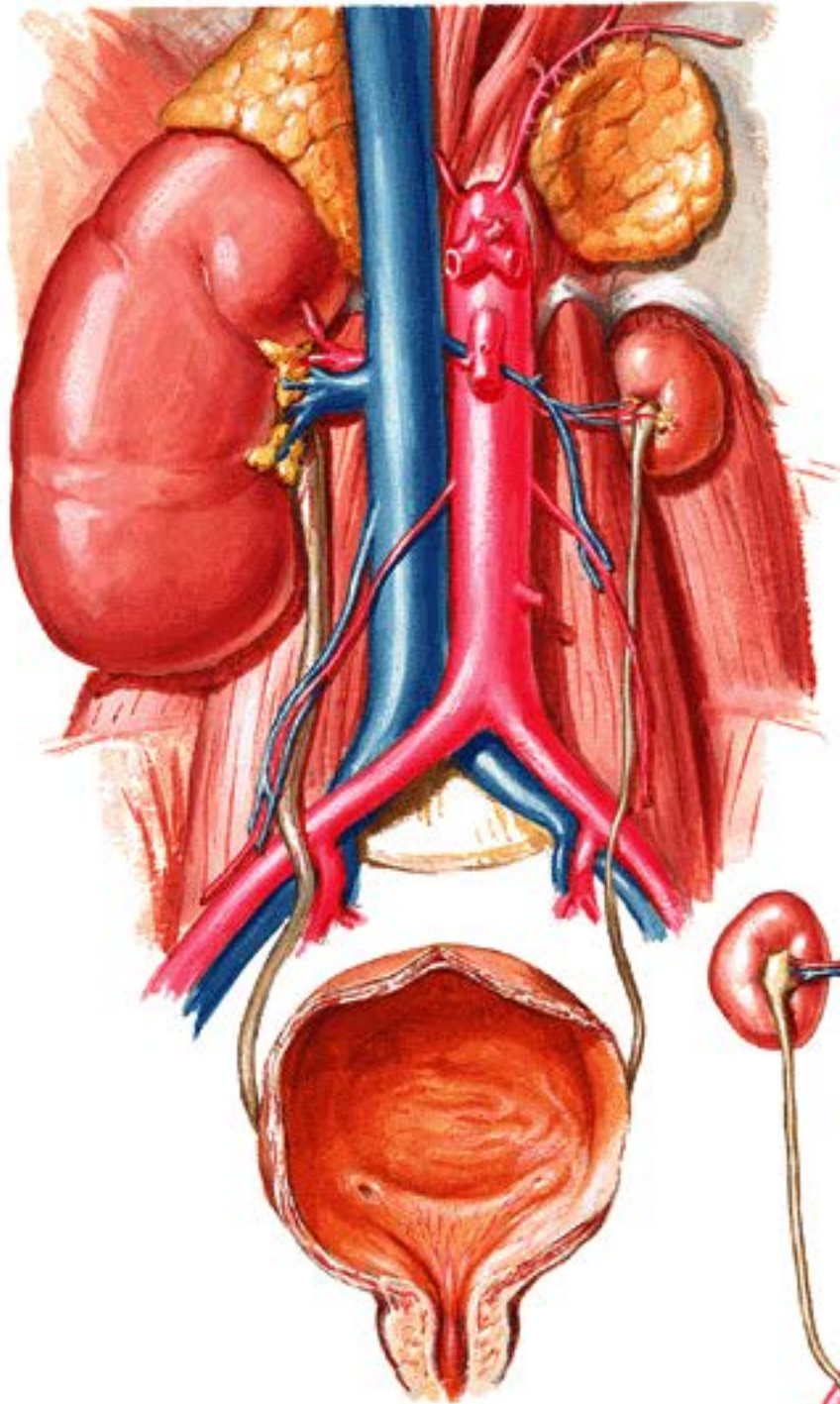


### Crossed ectopia of the right kidney





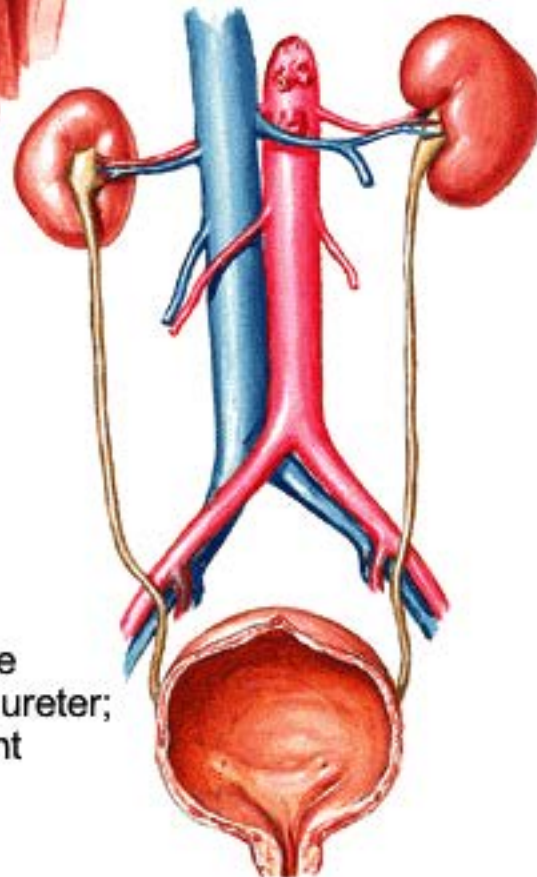
# Hypoplasia



Left unilateral hypoplasia of the kidney with narrow but patent ureter; both suprarenal glands present



Persistent fetal lobulation



Bilateral renal hypoplasia



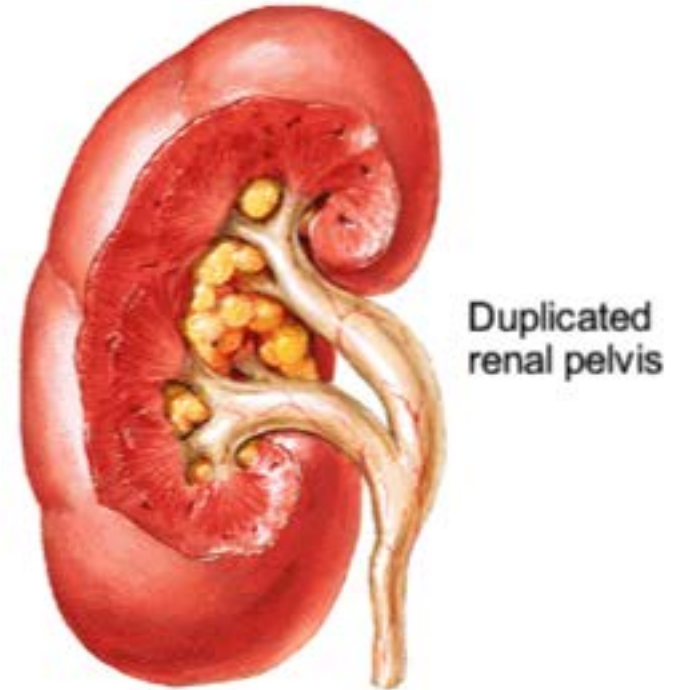
# Ureteric Bud Duplication

Incomplete duplication of ureter



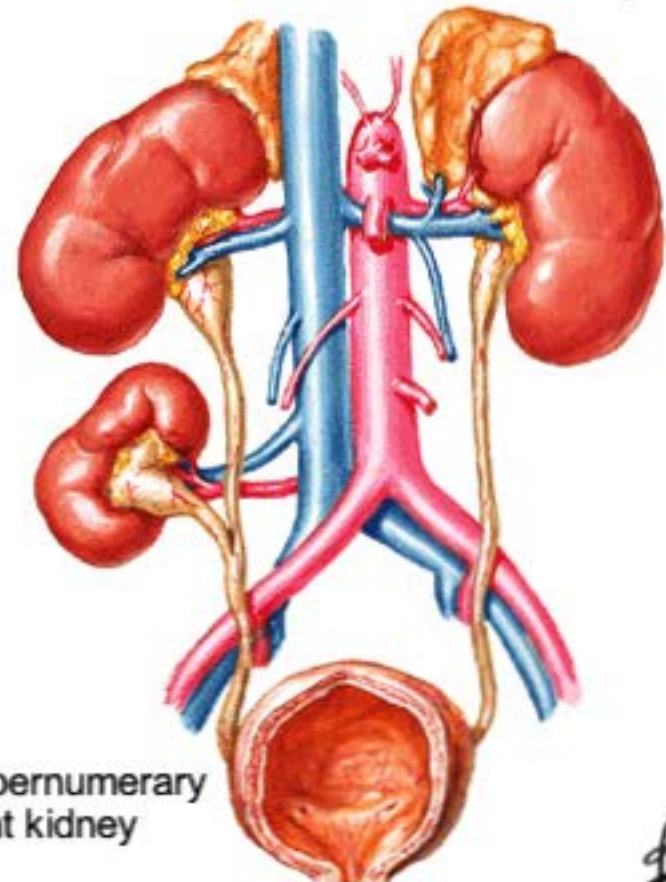
Bifid ureter: Duplicated ureters unite at variable distance between kidney and bladder

Anomalies of renal pelvis and calyces



Duplicated renal pelvis

Anomalies in number of kidneys

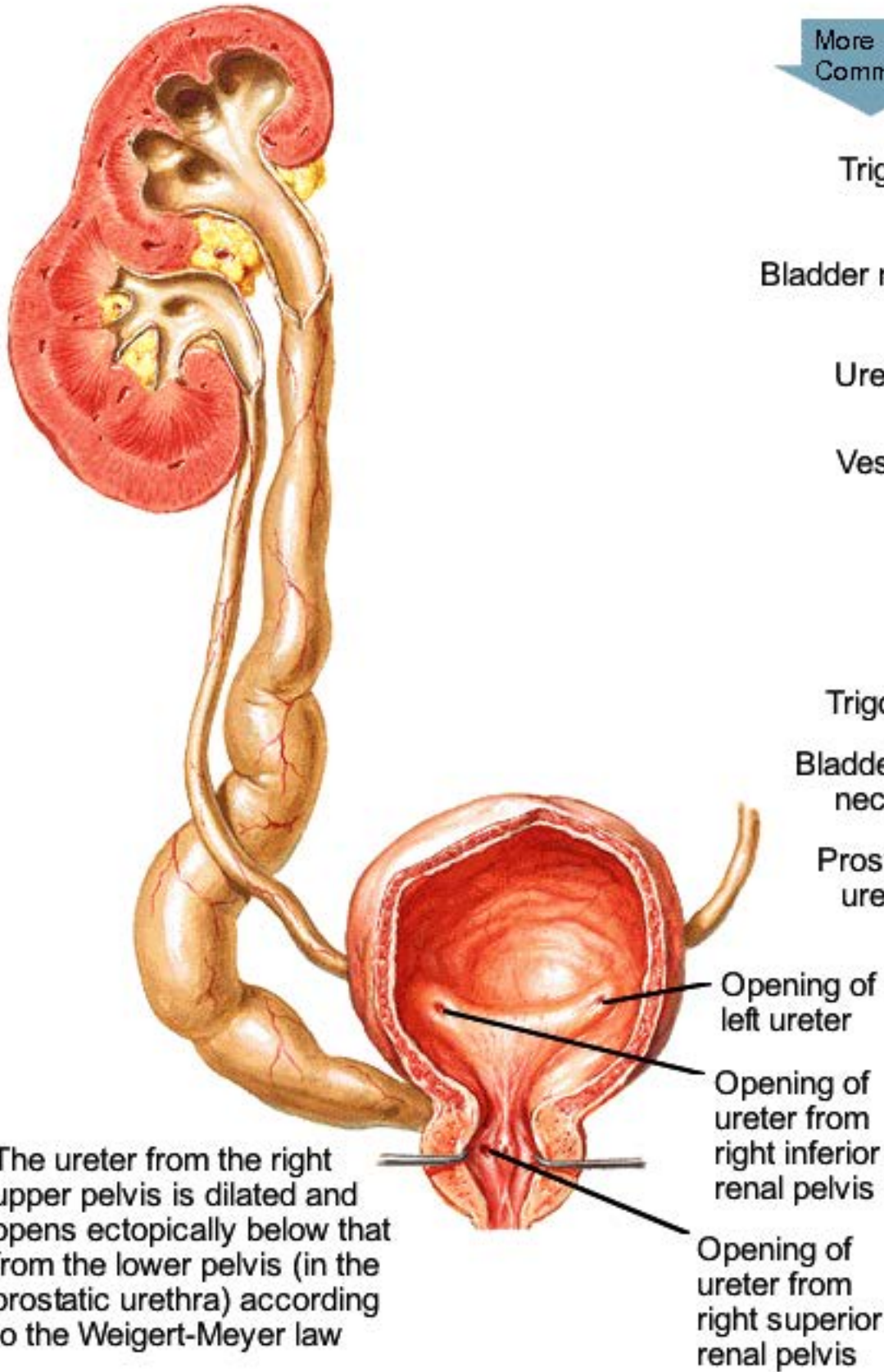


Supernumerary right kidney

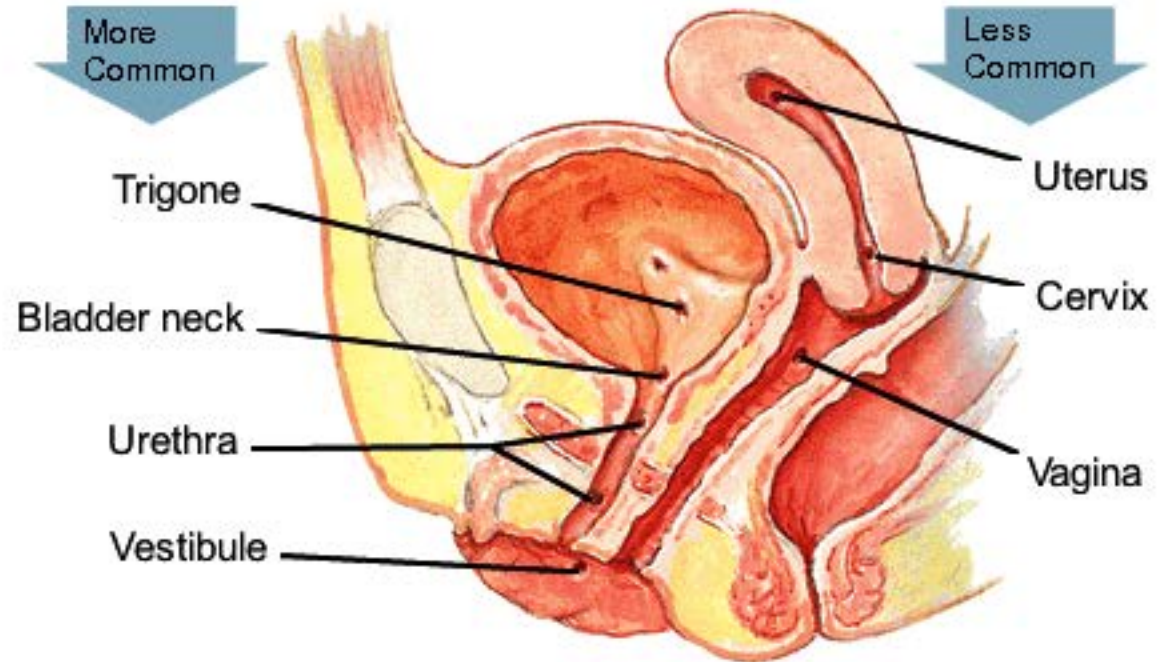


# Ectopic Ureters

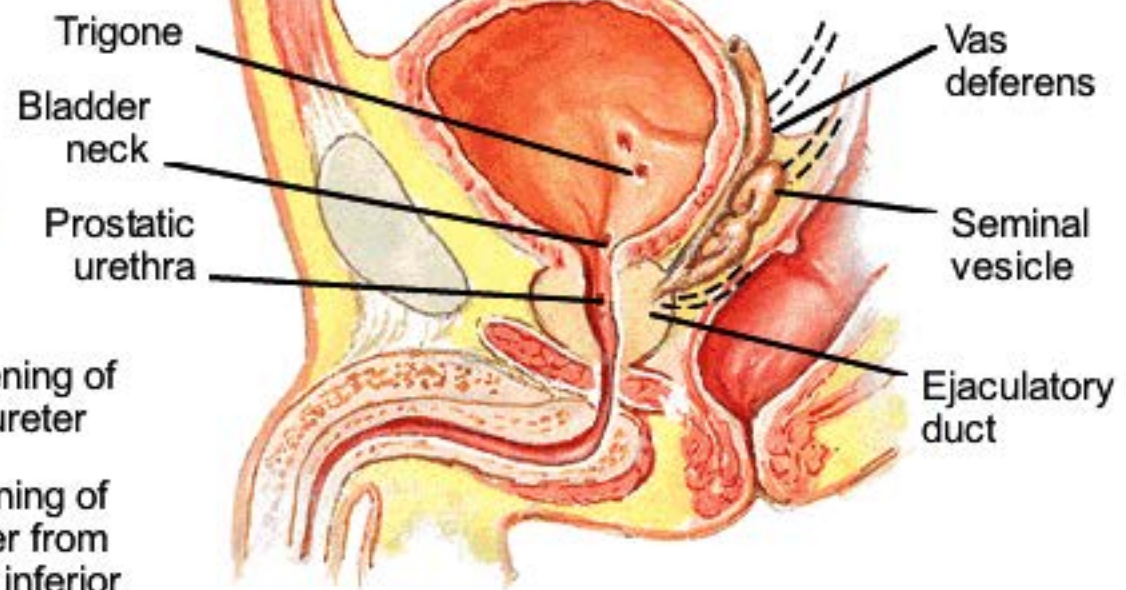
## Complete duplication of the ureter



## Observed sites of ectopic ureteral orifices



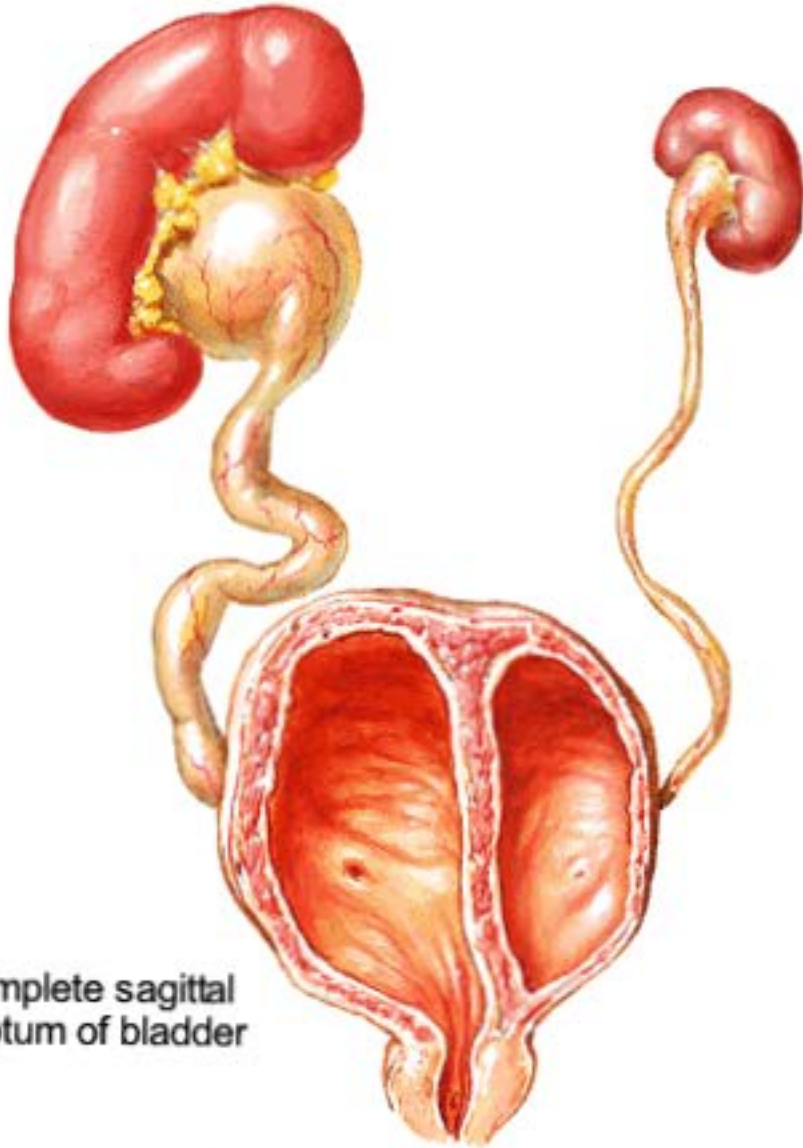
In the female



In the male



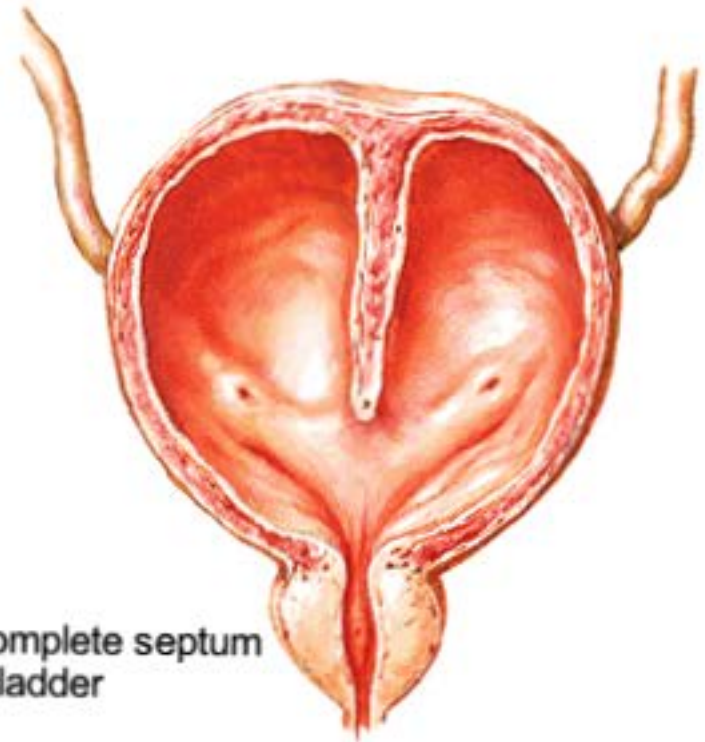
# Bladder Anomalies



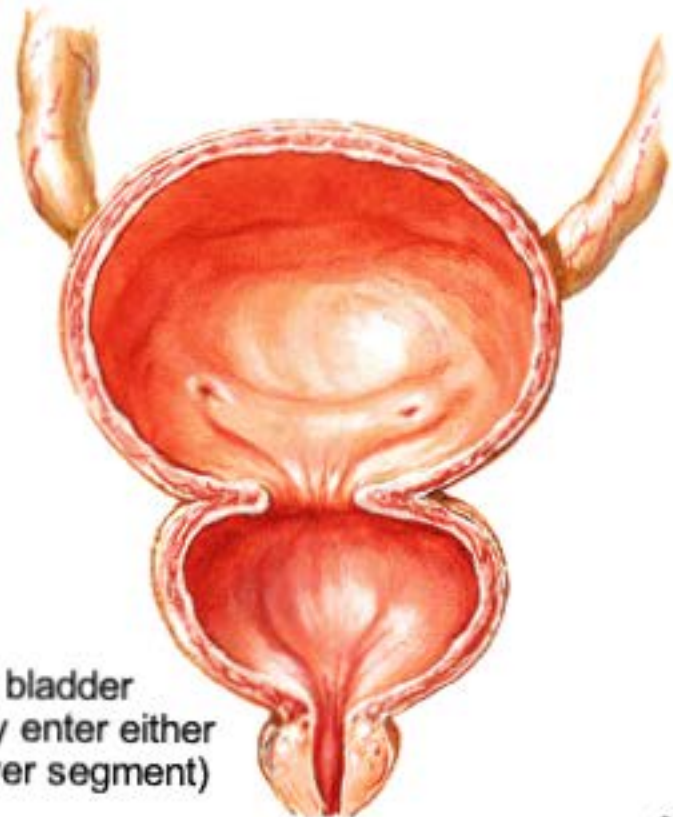
Complete sagittal  
septum of bladder



Incomplete duplication  
of bladder



Incomplete septum  
of bladder



"Hourglass" bladder  
(ureters may enter either  
upper or lower segment)

# Allantois/Urachus Anomalies



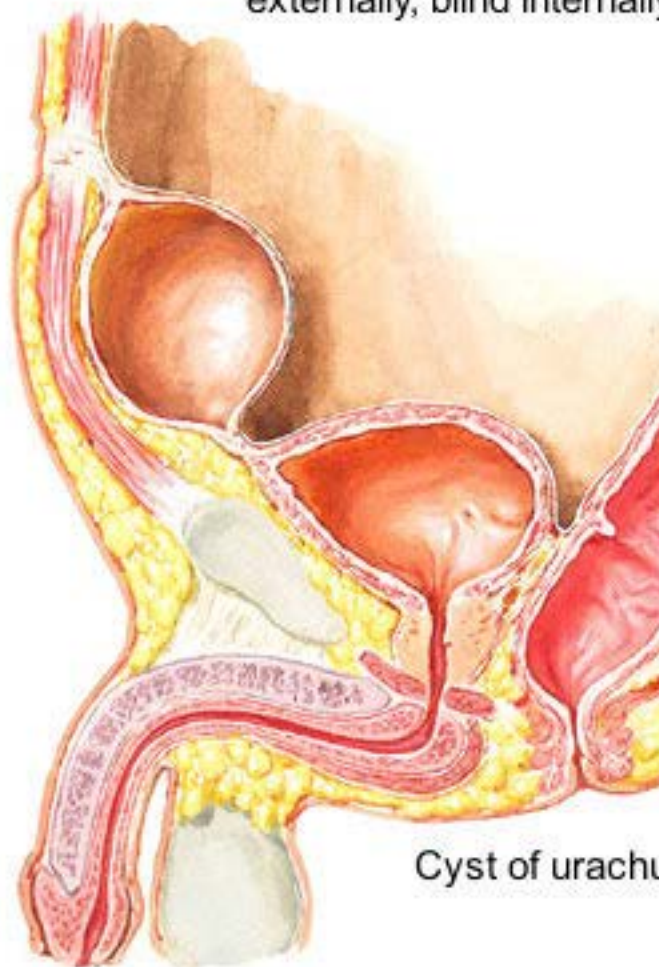
Completely patent urachus



Partially patent urachus; opening externally, blind internally



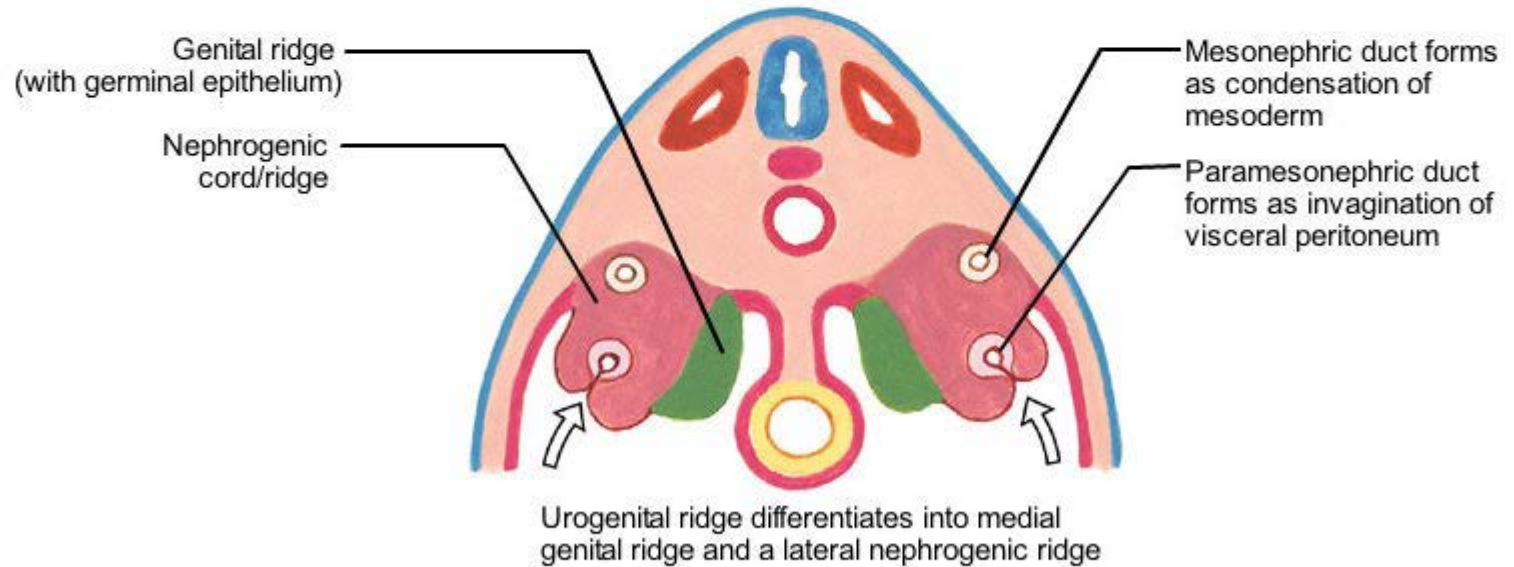
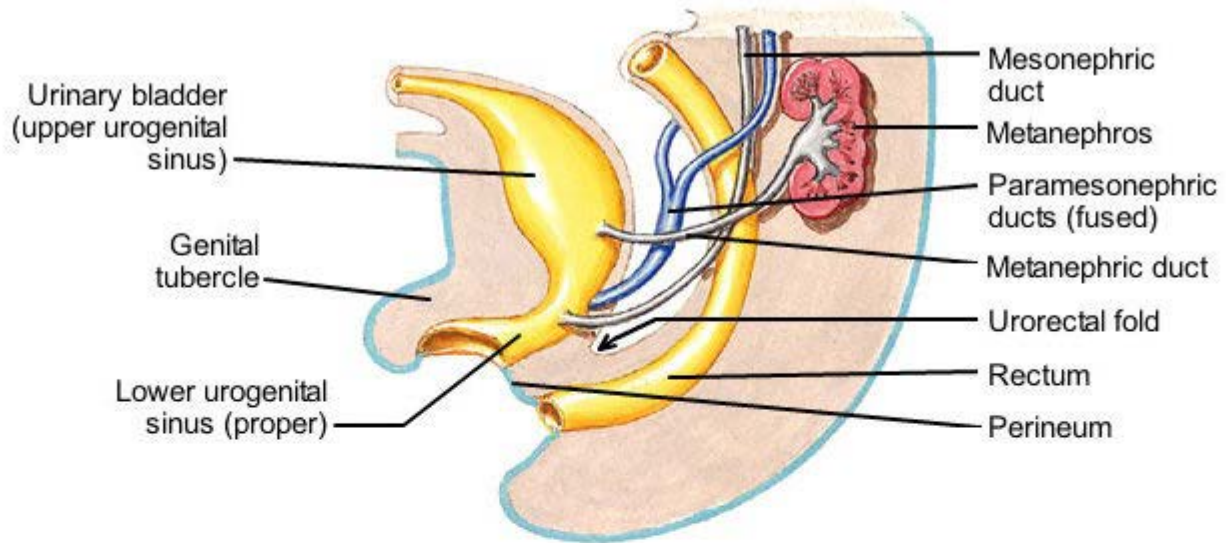
Partially patent urachus; opening internally, blind externally



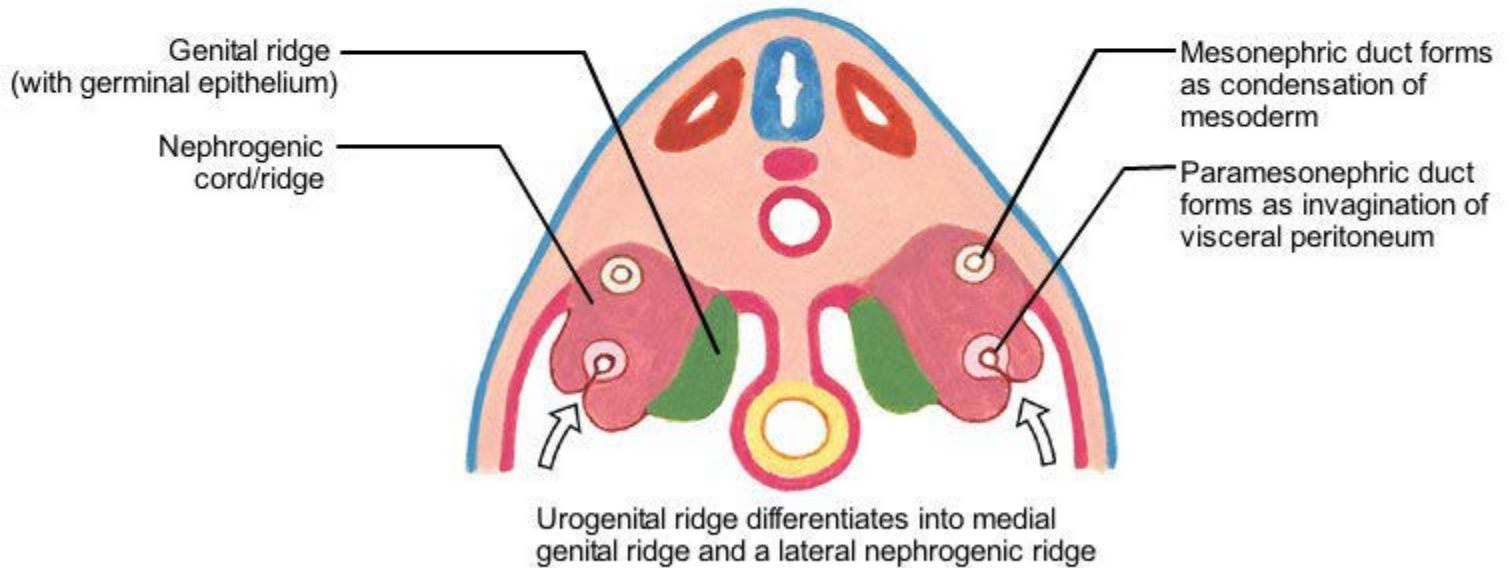
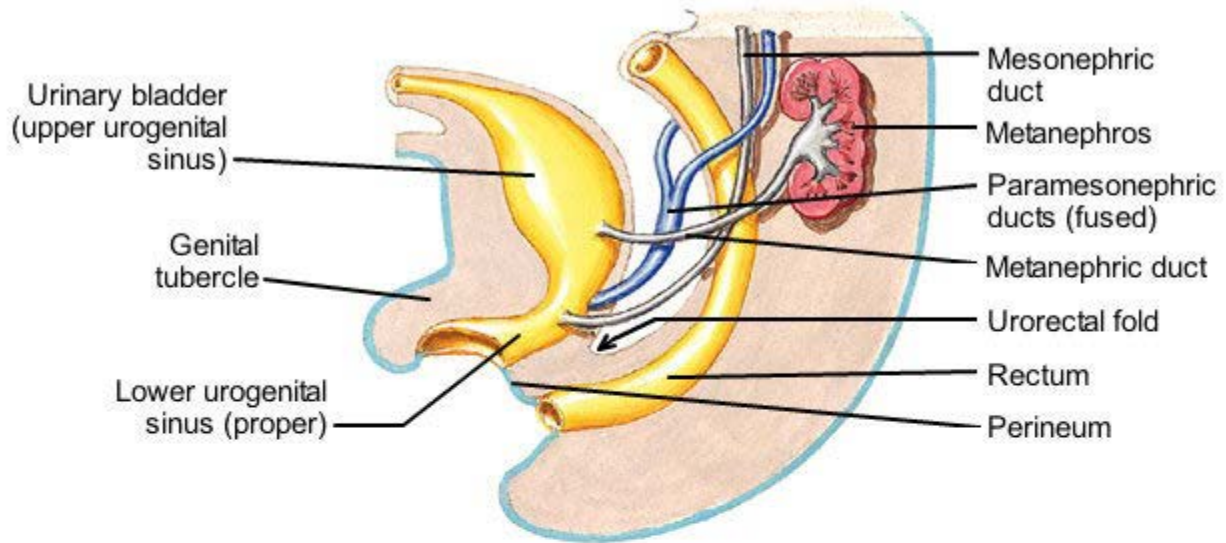
Cyst of urachus



# Primordia of the Genital System

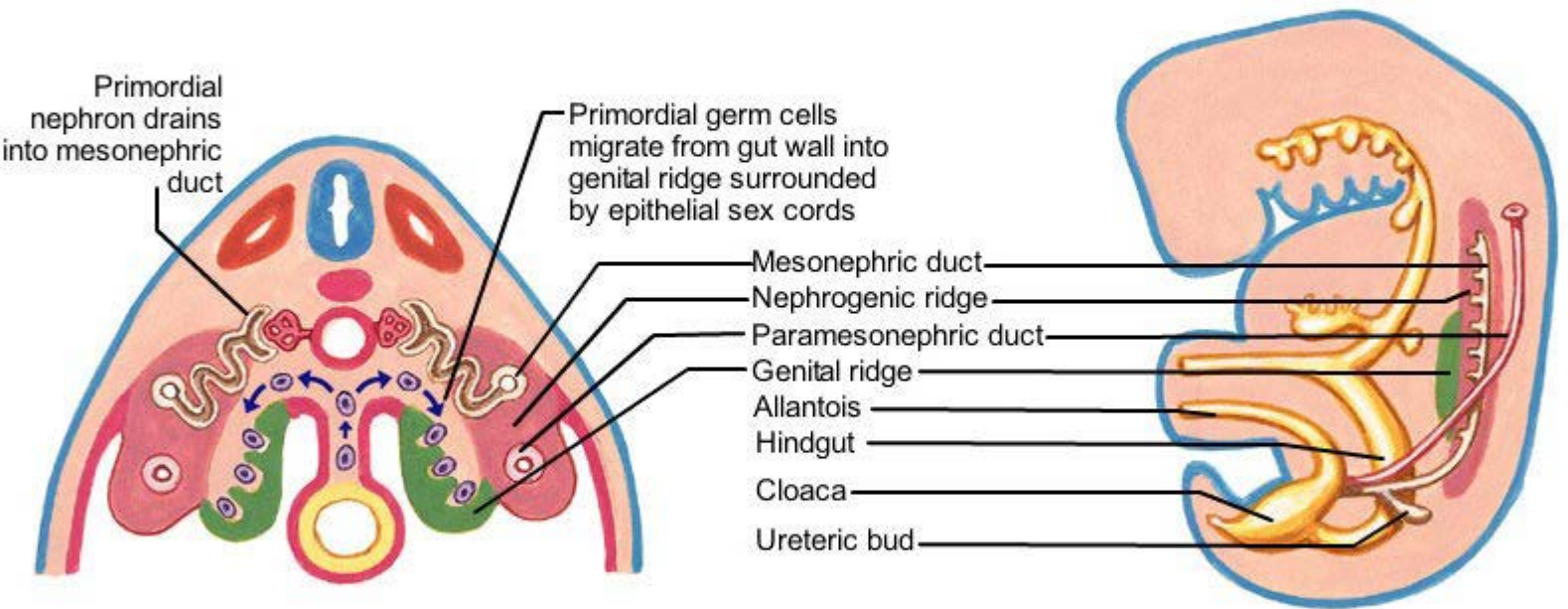


# Primordia of the Genital System



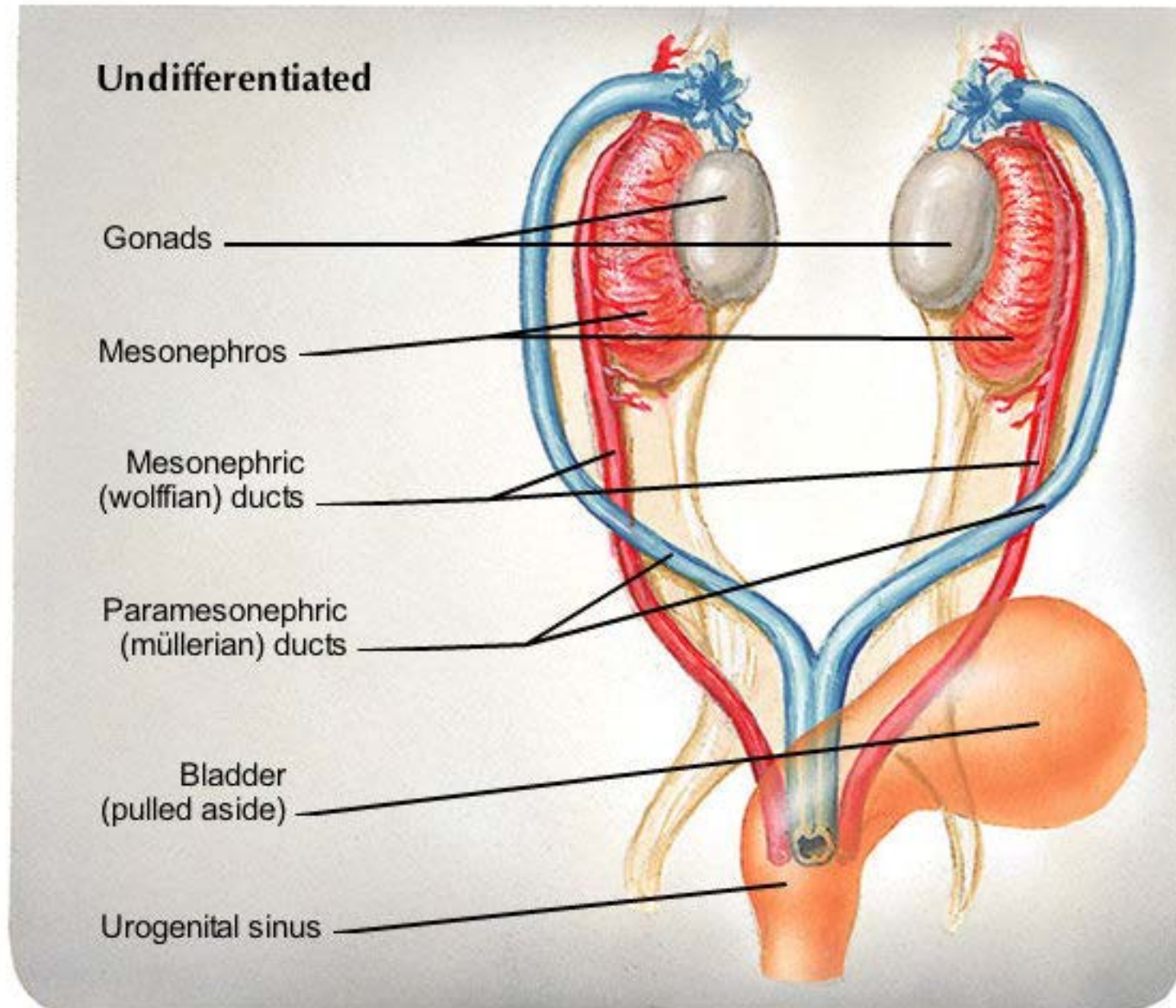


# Early Primordia



# 8-Week Undifferentiated (Indifferent) Stage

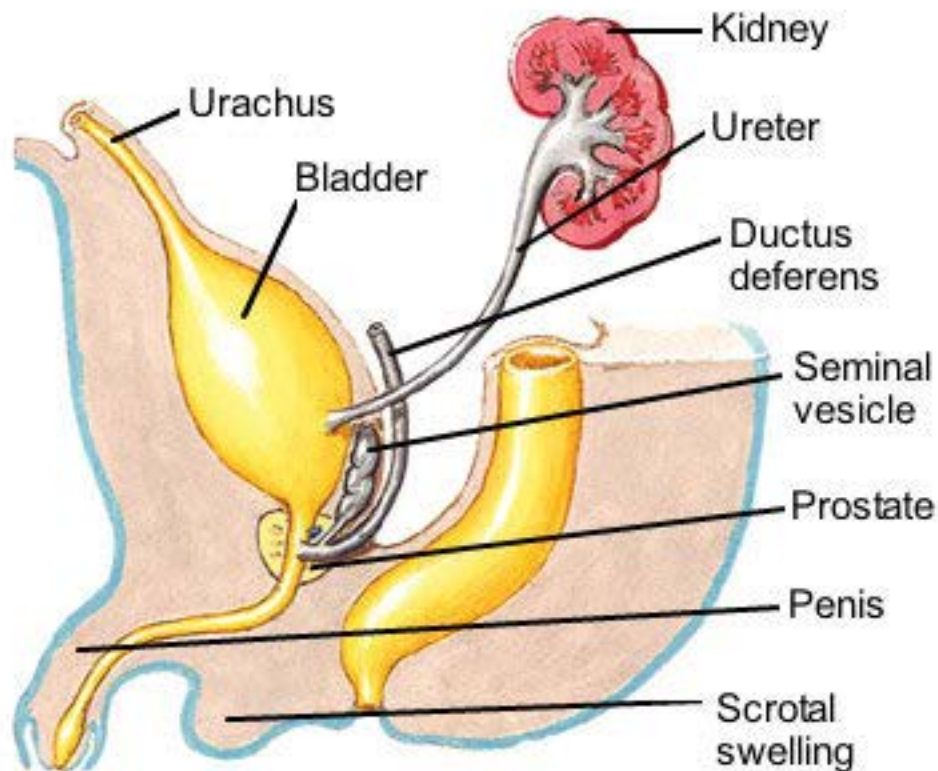
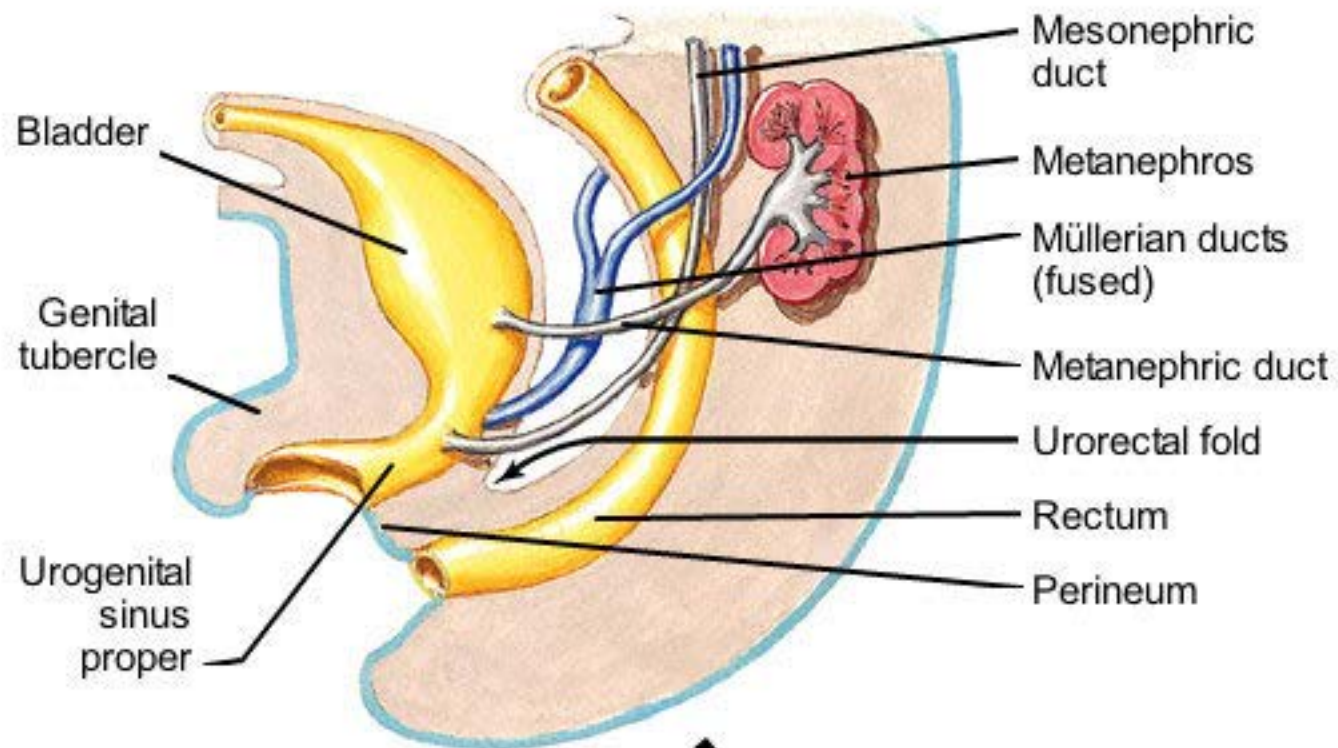
Anterior view (mesonephros will disappear in both sexes)



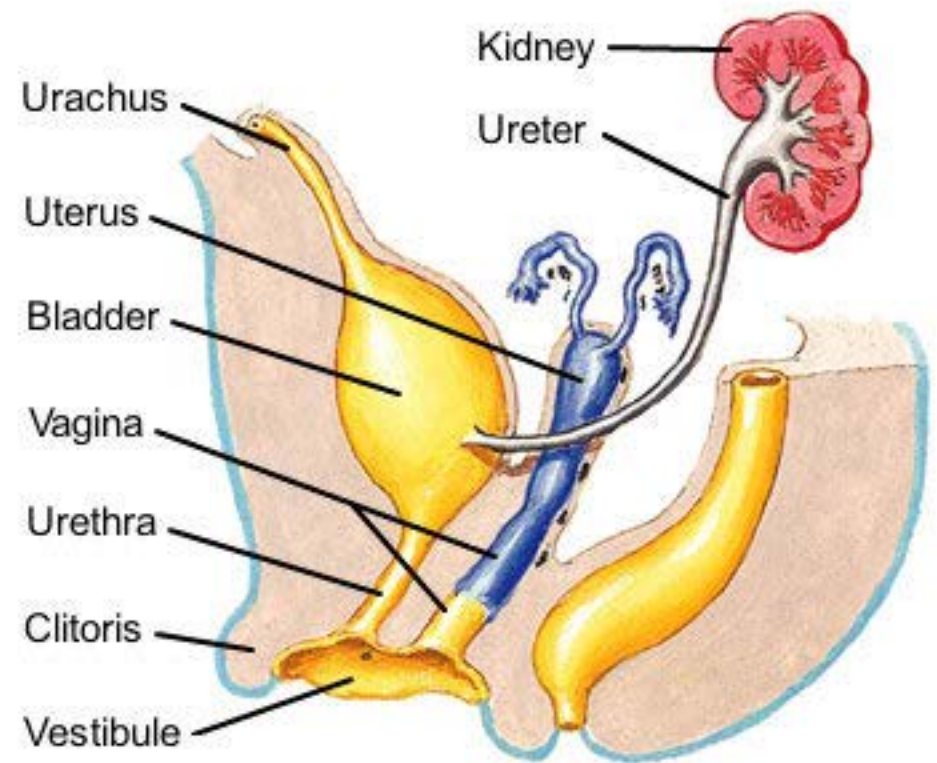


# 8-Week Undifferentiated (Indifferent) Stage

Lateral view (both sexes have identical primordia)

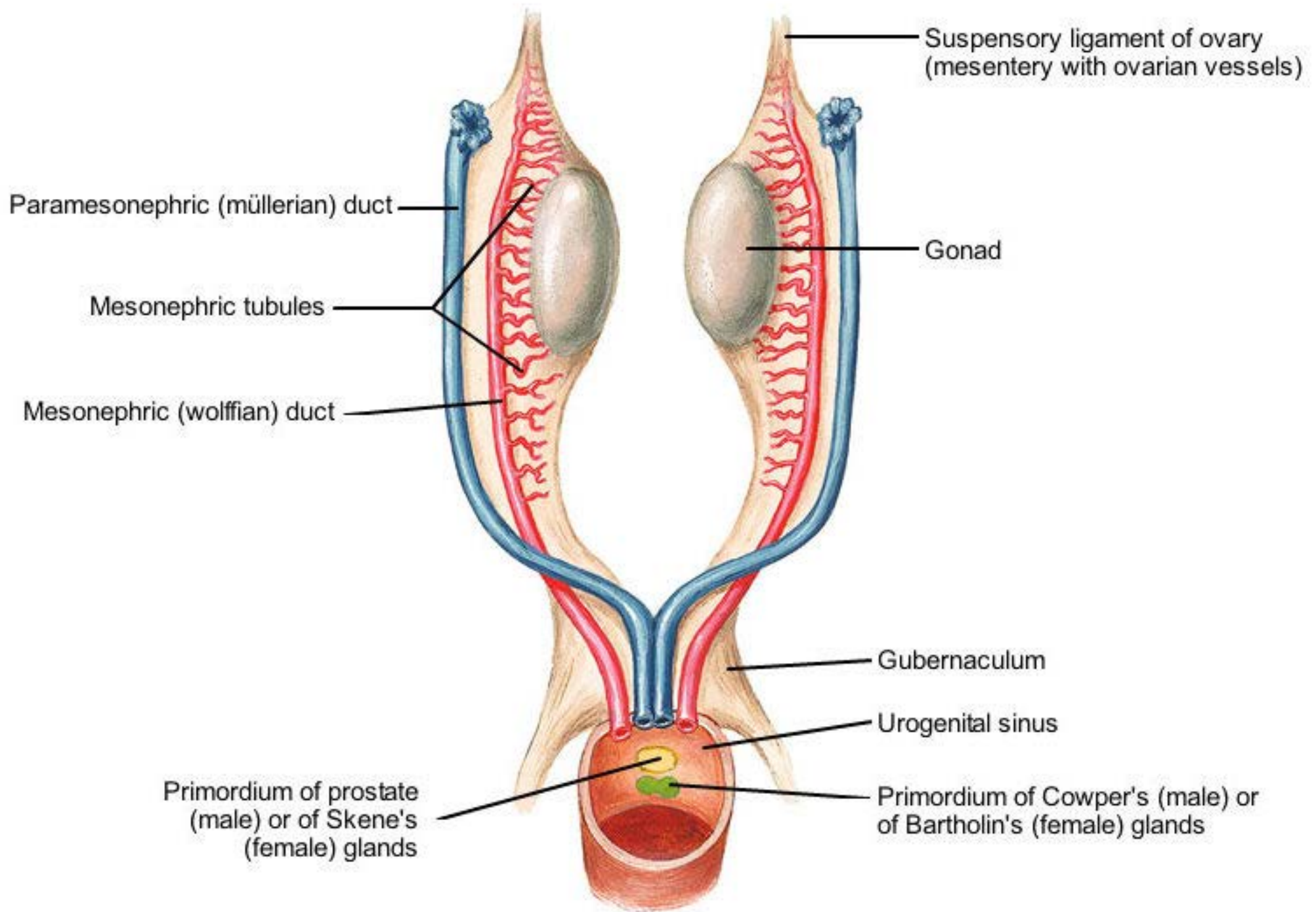


Male



Female

# Anterior View of the Derivatives



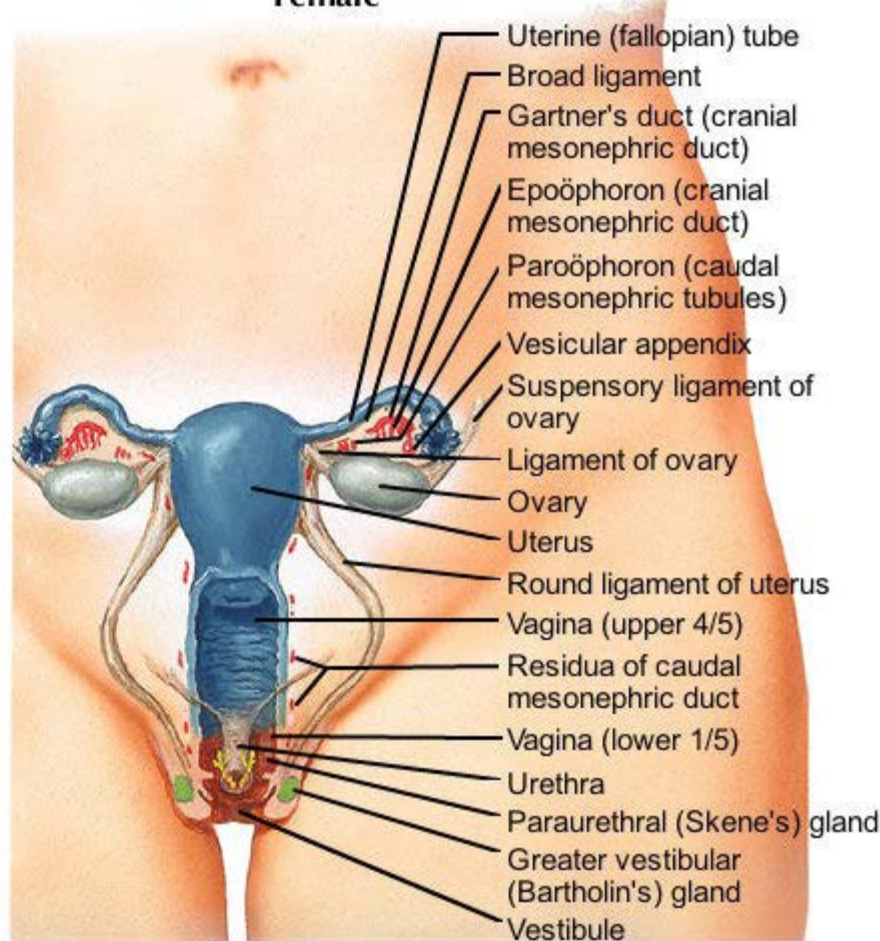
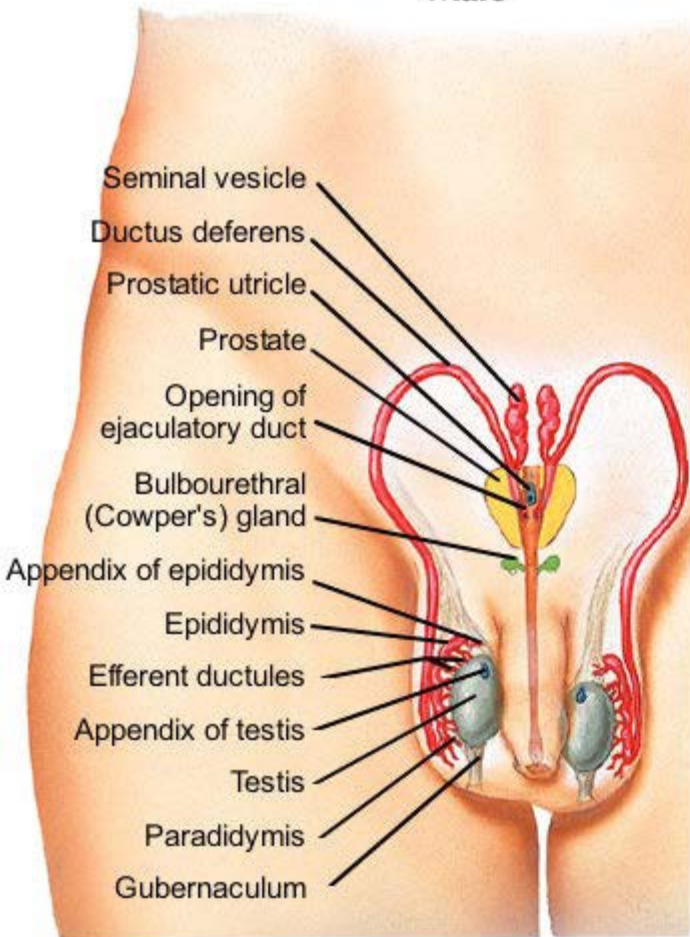


# Anterior View of the Derivatives

Undifferentiated

↙                      ↘

**Male**                      **Female**



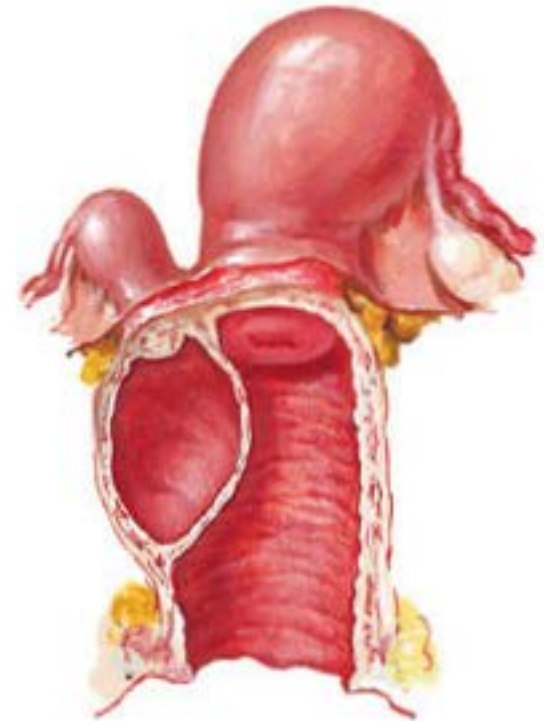
# Paramesonephric Duct Anomalies



Complete septum with double uterus and double vagina



Partial septum



Rudimentary second vagina without external opening, forming cyst



Bicornuate uterus with complete septum (double cervix)



Bicornuate uterus



Double uterus



Septate uterus



Partial septum



Unicornuate uterus



# Homologues of the External Genital Organs

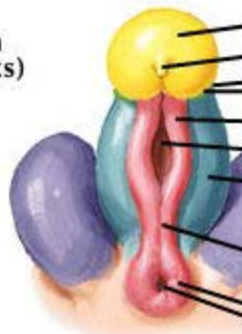
*F. Netter M.D.*  
© IGV

## Undifferentiated



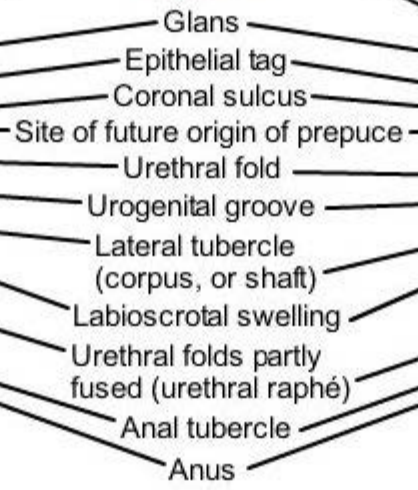
## Male

45-50 mm  
(~10 weeks)



## Female

45-50 mm  
(~10 weeks)

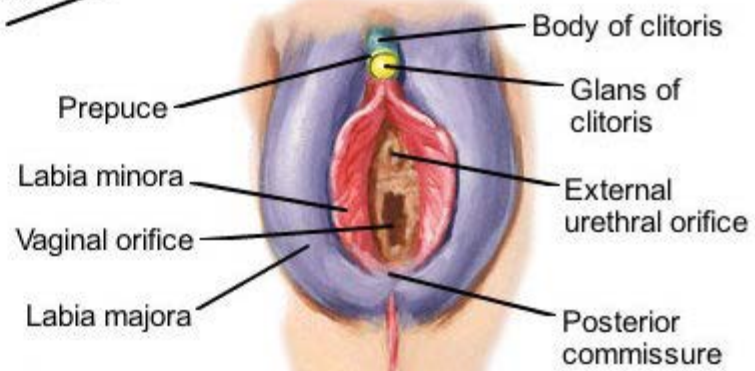


External urethral orifice  
Glans penis



Prepuce  
Body (shaft) of penis  
Raphé of penis  
Scrotum

Fully developed



Perineal raphe  
Perianal tissues (including external anal sphincter muscle)

Fully developed

# Hypospadia and Epispadias



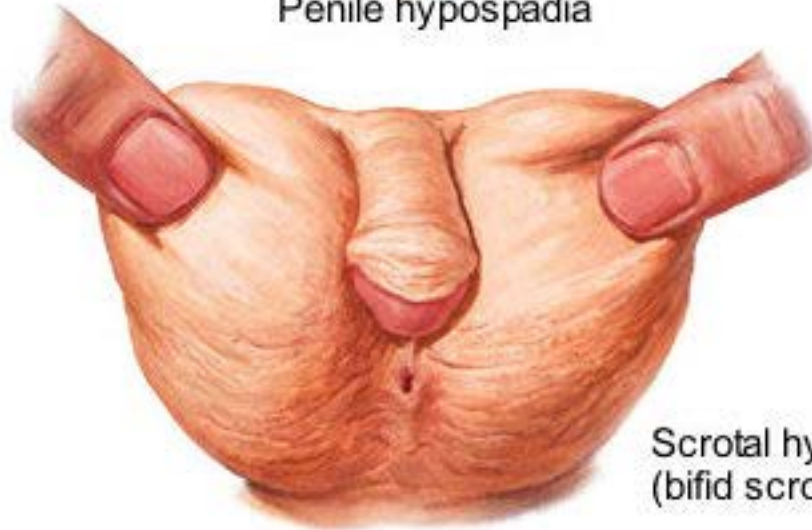
Glanular hypospadias



Penile hypospadias

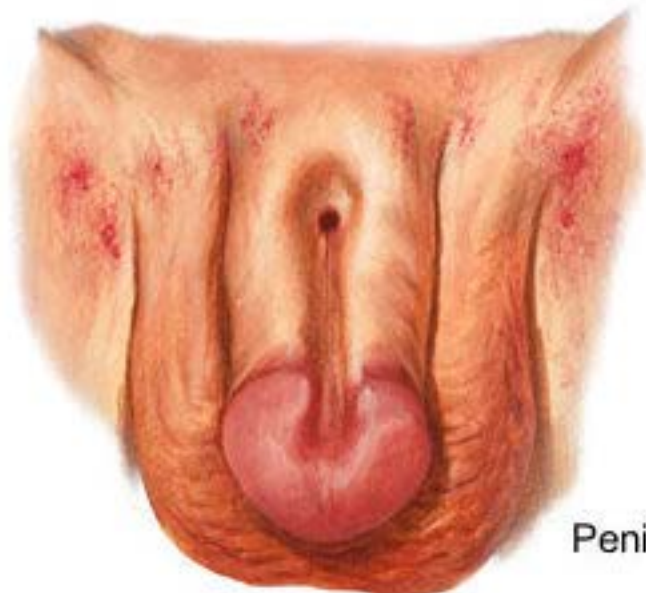


Penoscrotal hypospadias  
(with chordee)

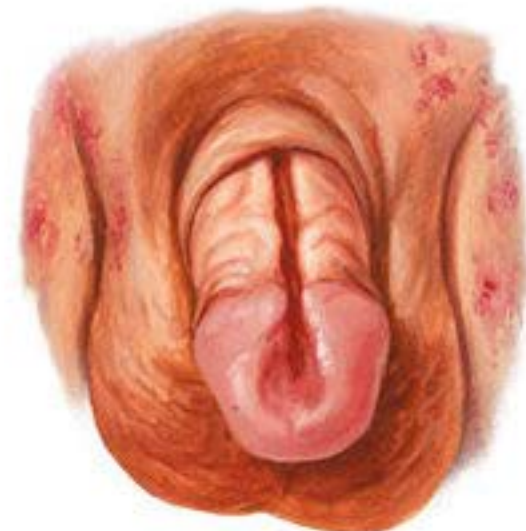


Scrotal hypospadias  
(bifid scrotum, chordee)

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Penile epispadias

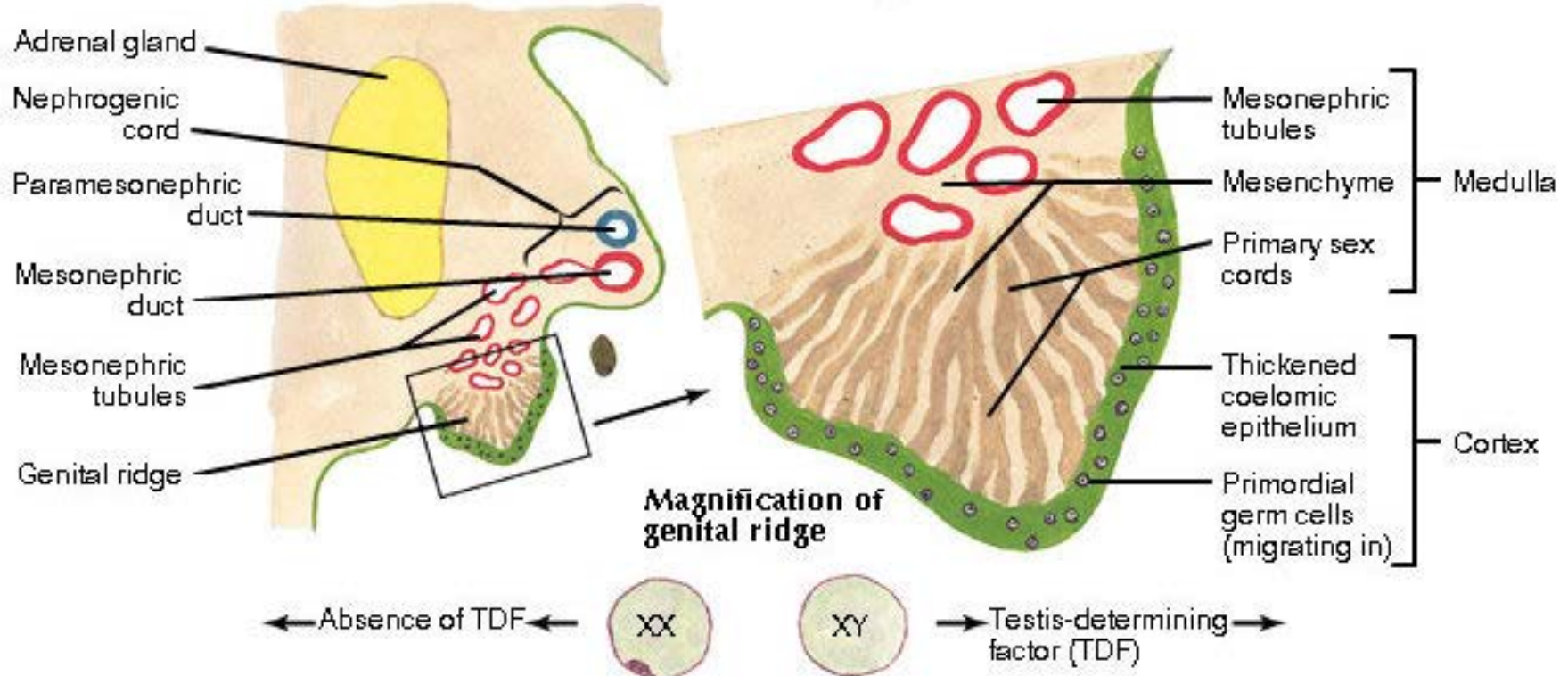


Complete epispadias

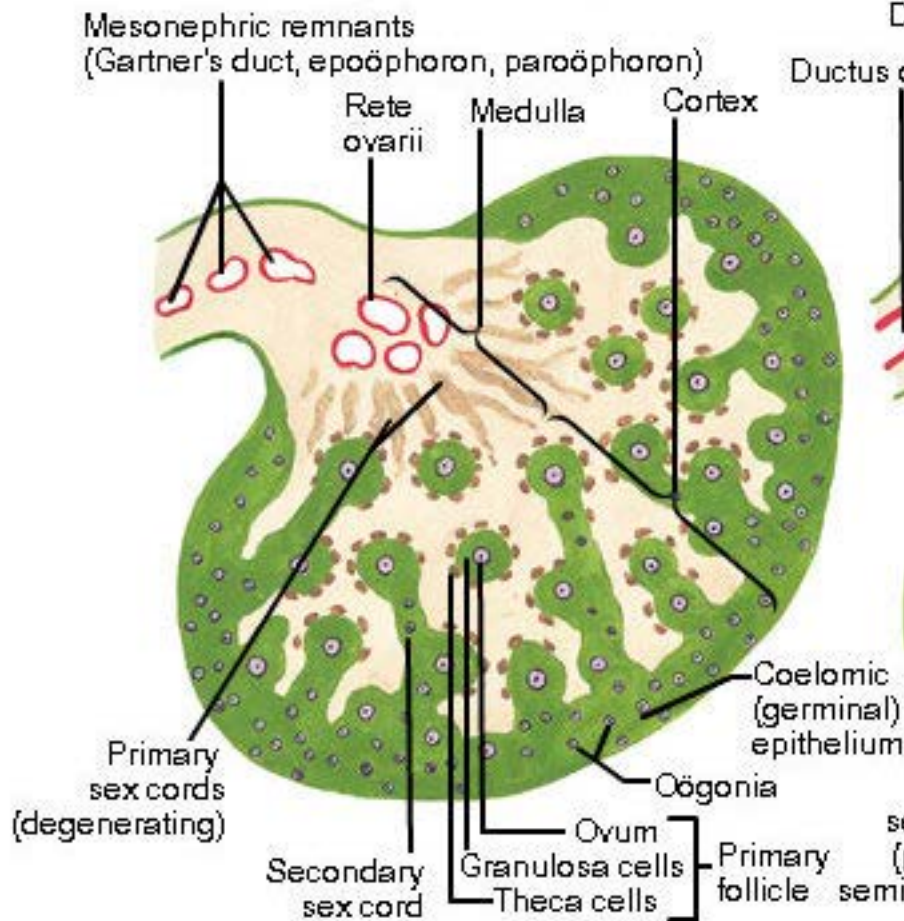


# Gonadal Differentiation

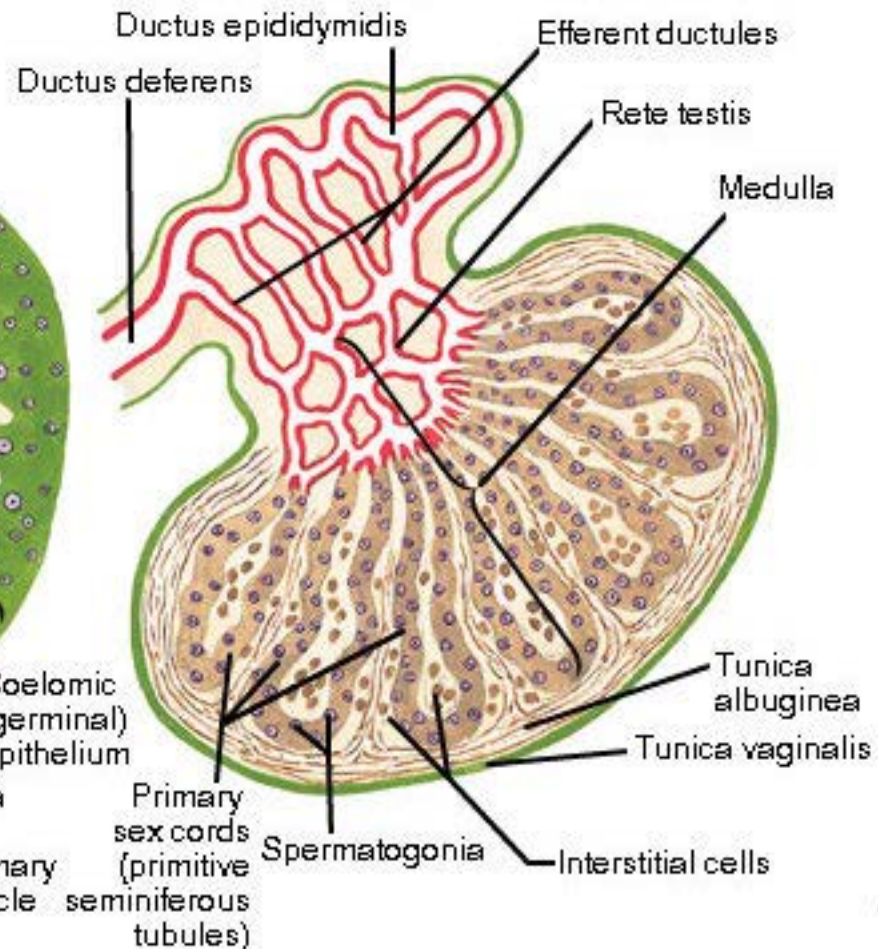
## Undifferentiated stage



## Female (primitive ovary)

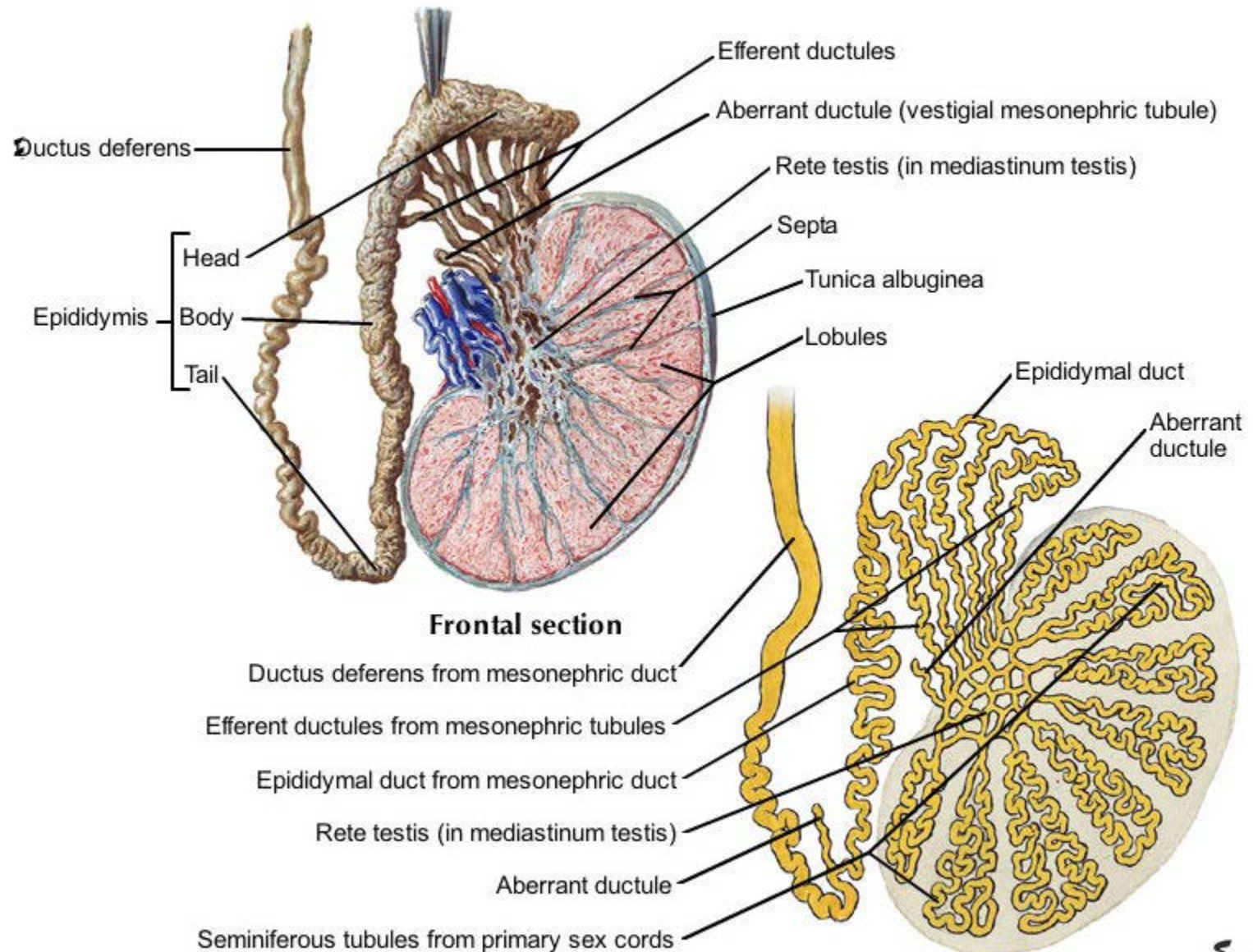


## Male (primitive testis)





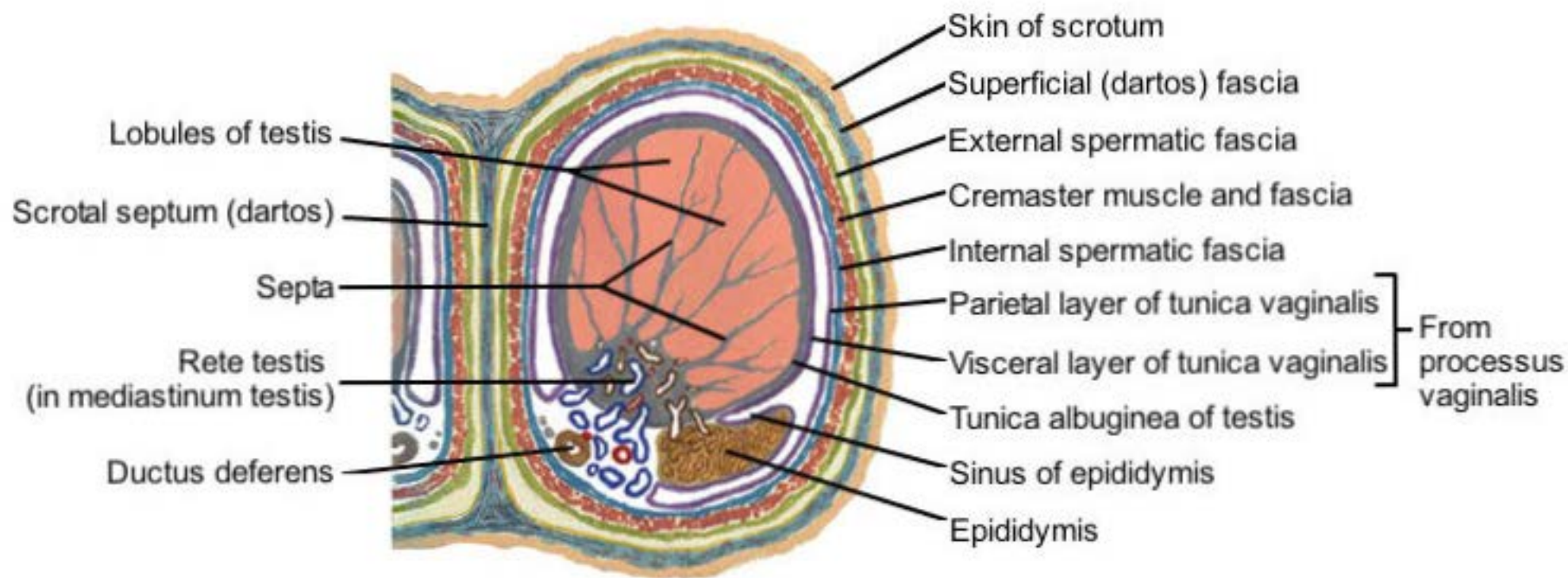
# Testis, Epididymis, and Ductus Deferens



Schema

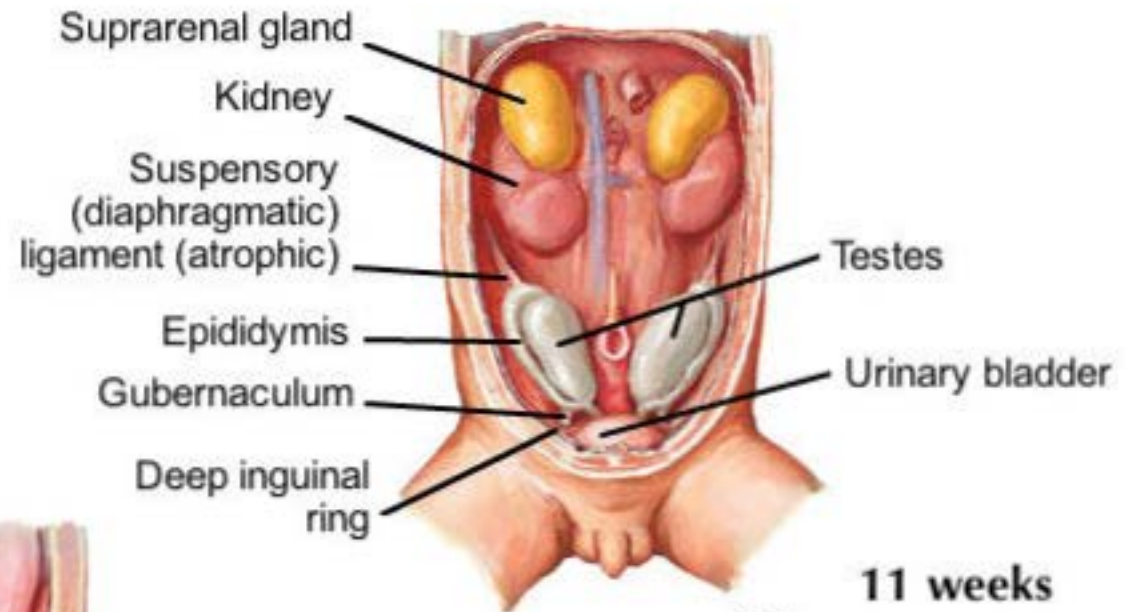


# Testis, Epididymis, and Ductus Deferens



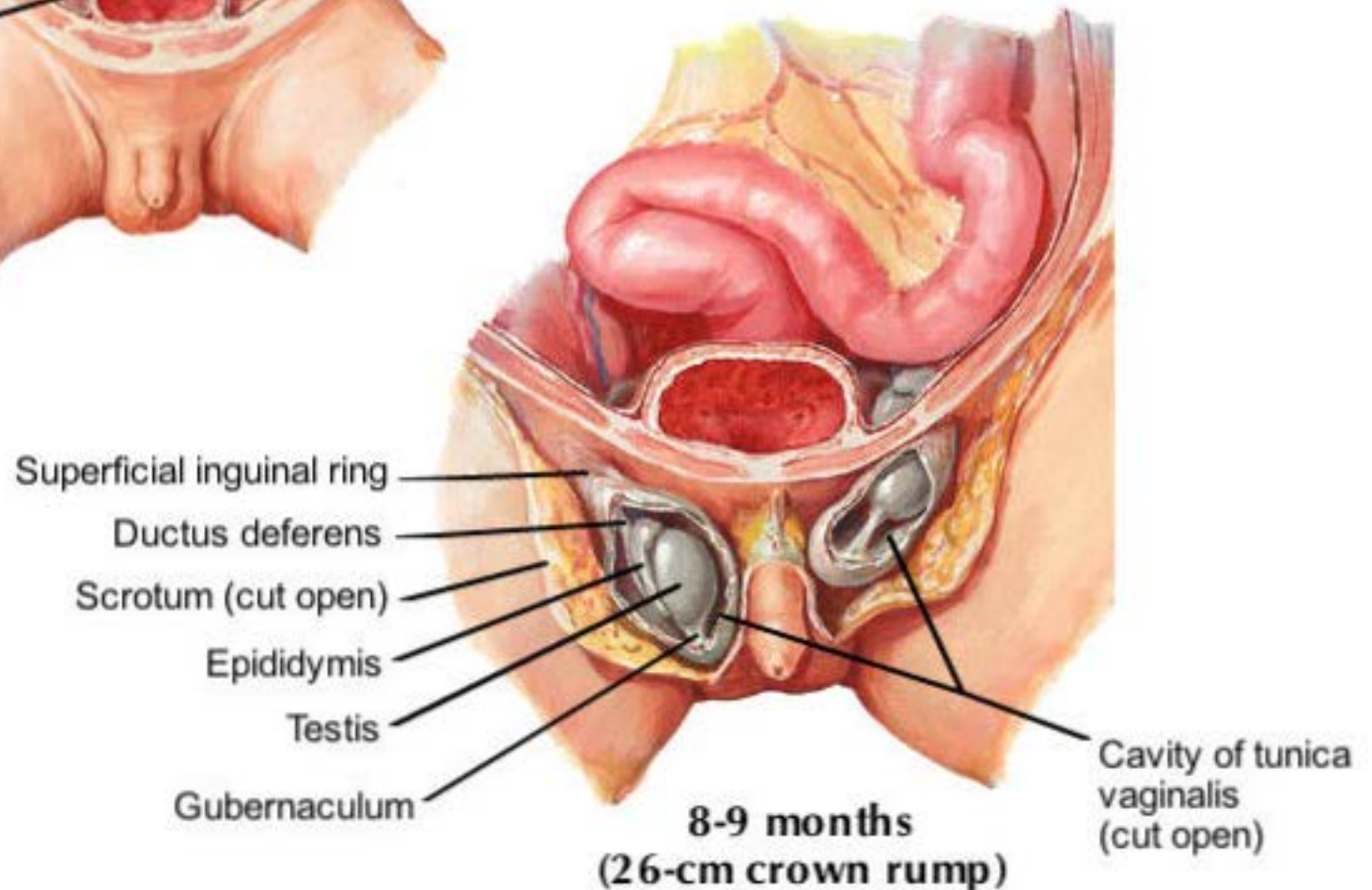
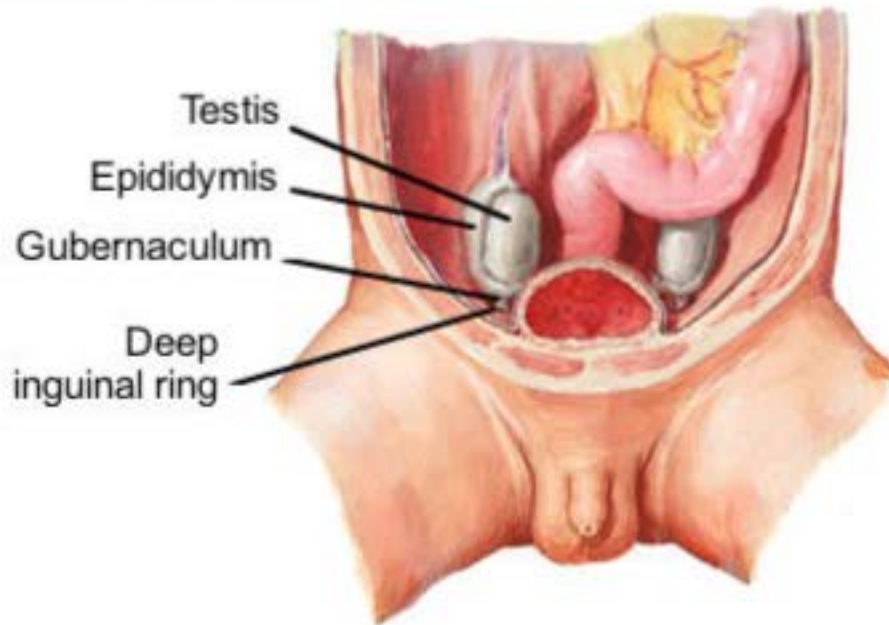
Cross section through scrotum and testis

# Descent of Testis



**11 weeks  
(43-mm crown rump)**

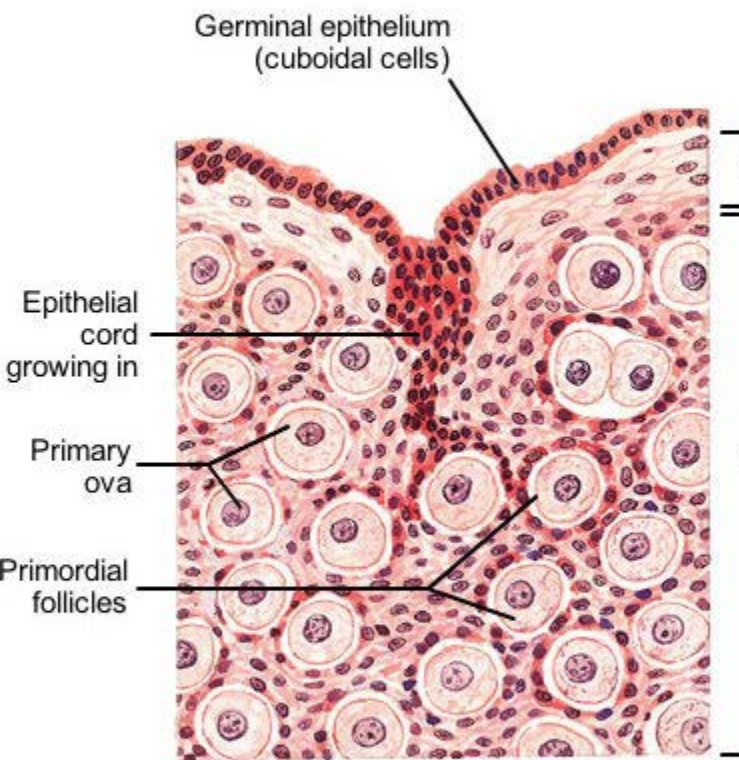
**4 months  
(107-mm crown rump)**



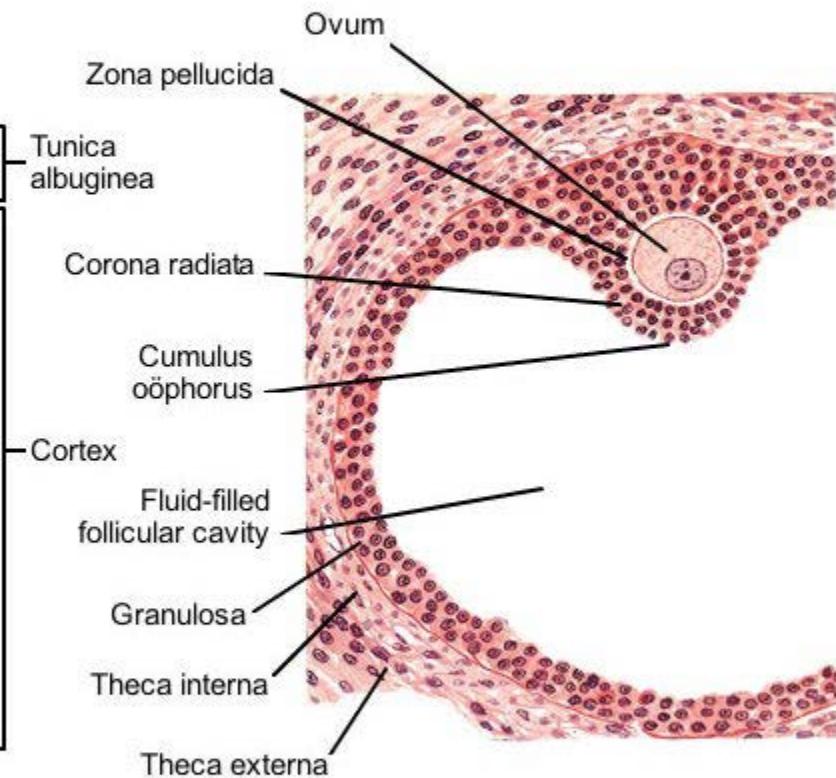
**8-9 months  
(26-cm crown rump)**



# Ova and Follicles



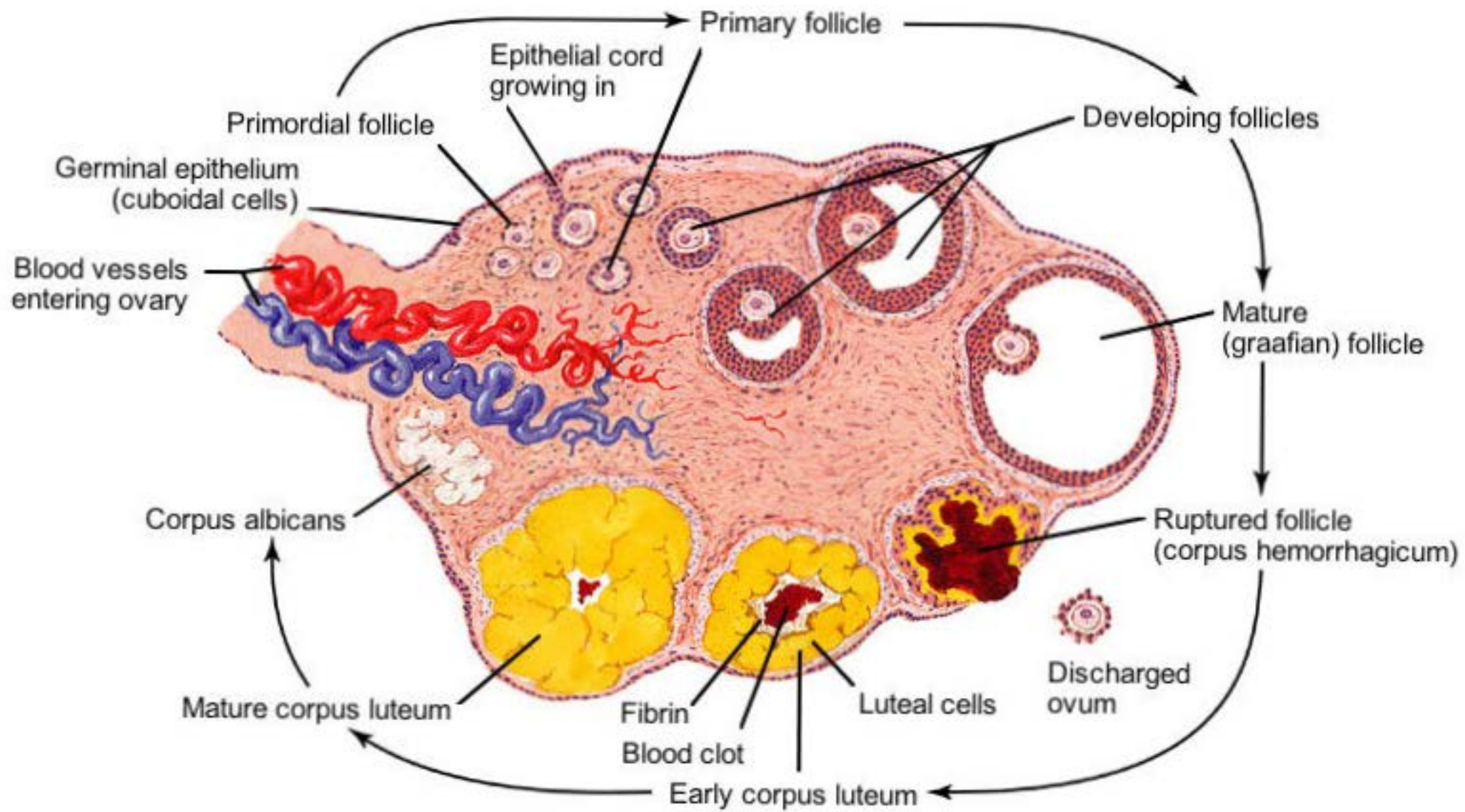
**Infant ovary**



**Maturing follicle**

# Ova and Follicles

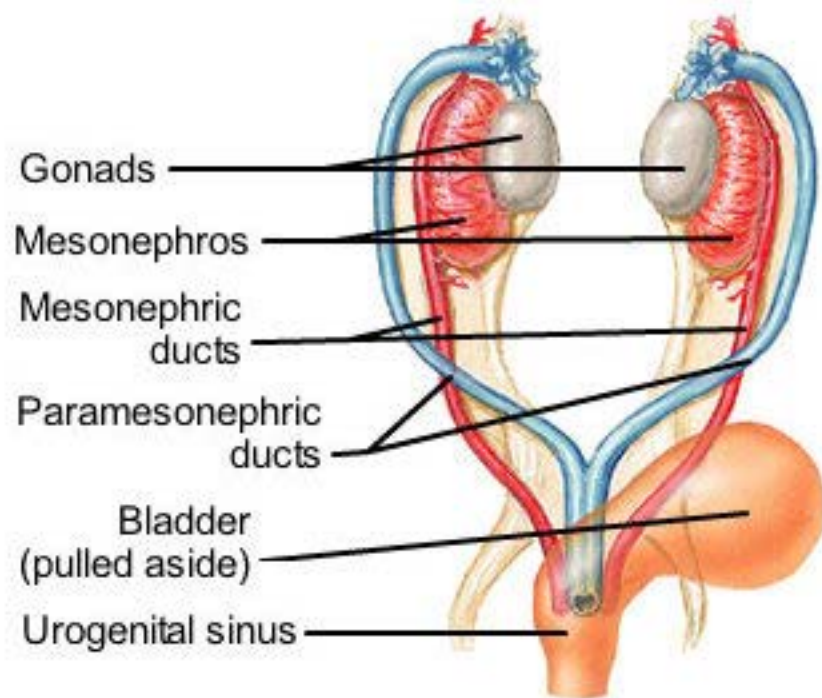
## Stages of ovum and follicle



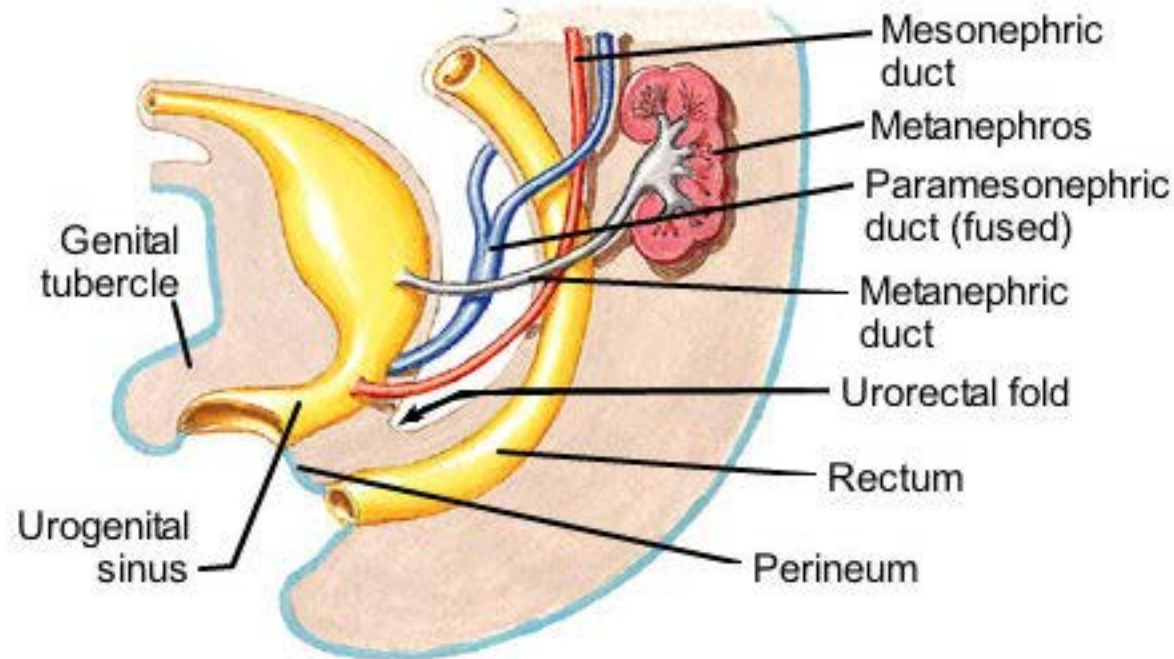


# Summary of Urogenital Primordia and Derivatives

## Undifferentiated

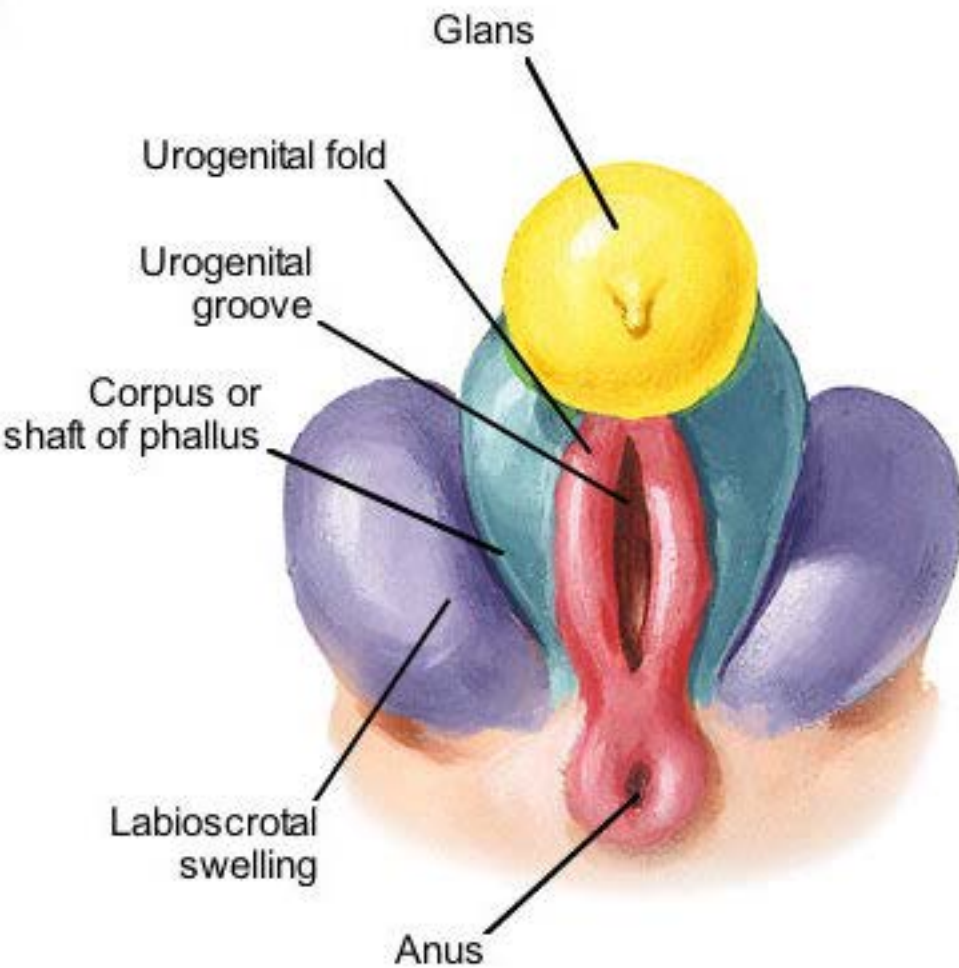


8-week indifferent stage, anterior view

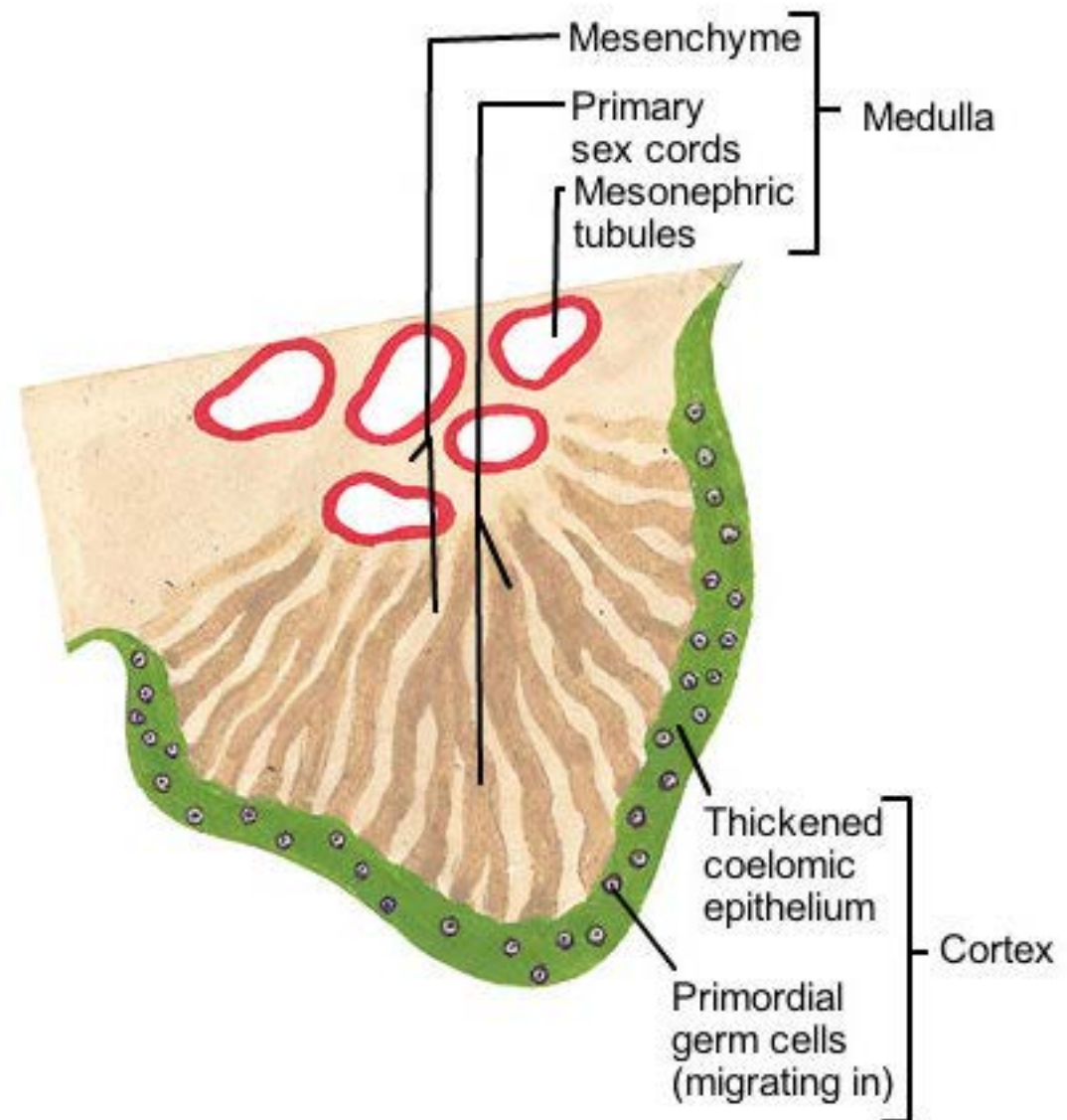


8-week indifferent stage, lateral view  
(gonad not shown)

# Summary of Genital Primordia and Derivatives



10-week external genitalia primordia



Indifferent gonad developing from genital ridge



# Urogenital Primordia and Derivatives

Female	Male
<b>From the Urogenital Sinus</b>	
Urinary bladder Urethra Lower vagina (and vaginal epithelium) Vestibule Greater vestibular/urethral glands	Urinary bladder Urethra (except navicular fossa) Prostate gland Bulbourethral glands
	Vestigial: prostatic utricle
<b>From the Mesonephric Duct and Tubules</b>	
Ureteric bud from mesonephric duct forms: Ureter Renal pelvis Major and minor calices Collecting tubules	Efferent ductules Duct of epididymis Ductus deferens Ejaculatory duct Seminal vesicles Ureter, renal pelvis, calices, and collecting tubules
Vestigial: epoophoron, paroophoron, appendix vesiculosa, Gartner's duct	Vestigial: appendix of testis
<b>From the Paramesonephric Duct</b>	
Uterine tubes, uterus, upper vagina	Vestigial: appendix of testis
Vestigial: hydatid	

# Genital Primordia and Derivatives

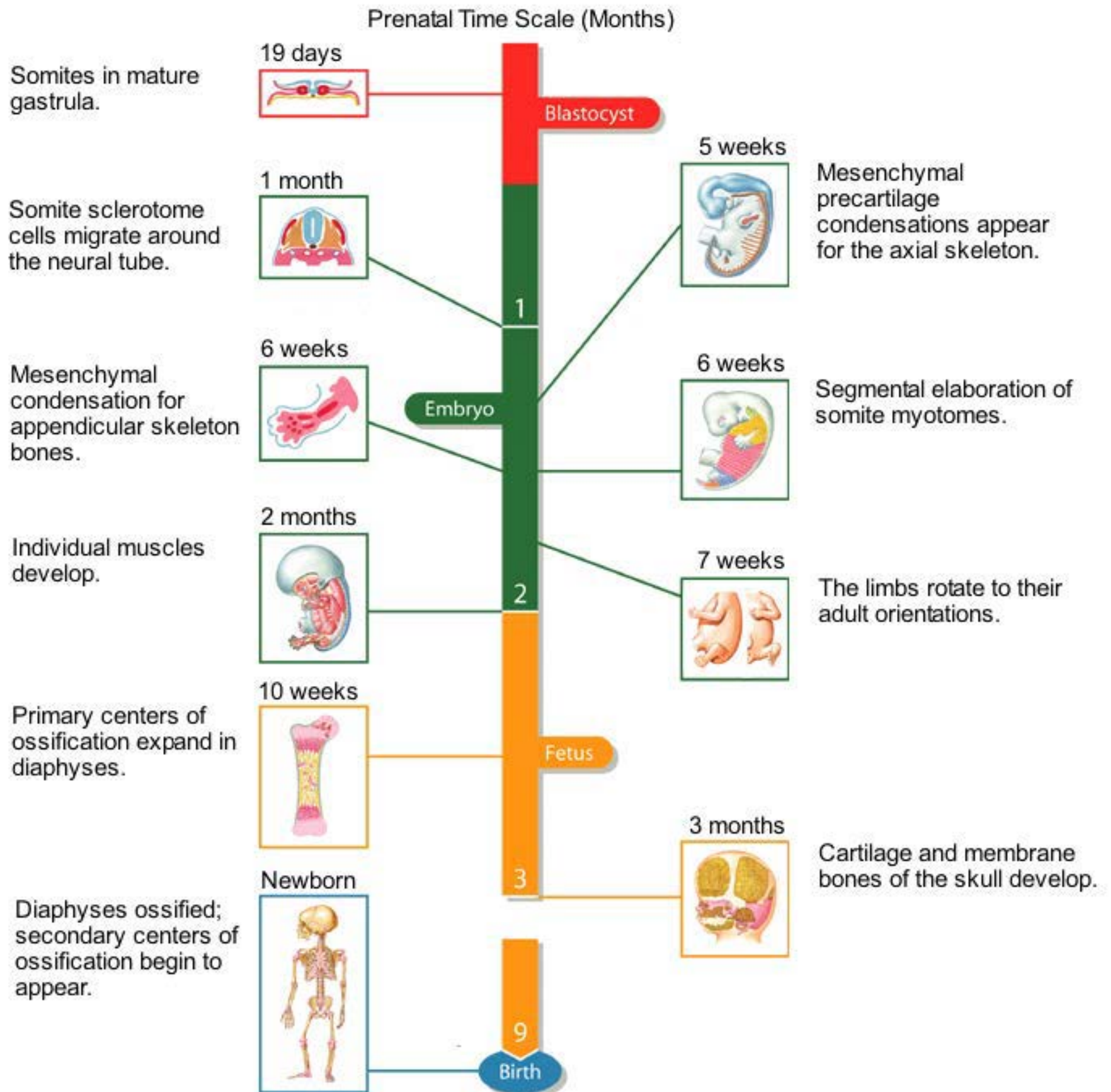
## GENITAL PRIMORDIA AND DERIVATIVES

Female	Male
From the Genital Tubercle/Phallus	
Clitoris: Glans clitoridis Corpora cavernosa clitoridis Bulb of the vestibule	Penis: Glans penis (and navicular fossa) Corpora cavernosum penis Corpus spongiosum penis
From the Urogenital Folds	
Labia minora Perineal raphé Perianal tissue (and external anal sphincter)	Ventral aspect of penis Most of the penile urethra Perineal raphé Perianal tissue (and external sphincter)
From the Labioscrotal Folds	
Labia majora	Scrotum
From the Indifferent Gonad	
Ovary: follicles from secondary sex cords in cortex	Testis: seminiferous tubules from primary sex cords Rete testis in medulla
Vestigial: rete ovarii in medulla	
From the Gubernaculum	
Ovarian ligament Round ligament of the uterus	Gubernaculum testis

© IGCN



# THE MUSCULOSKELETAL SYSTEM TIMELINE

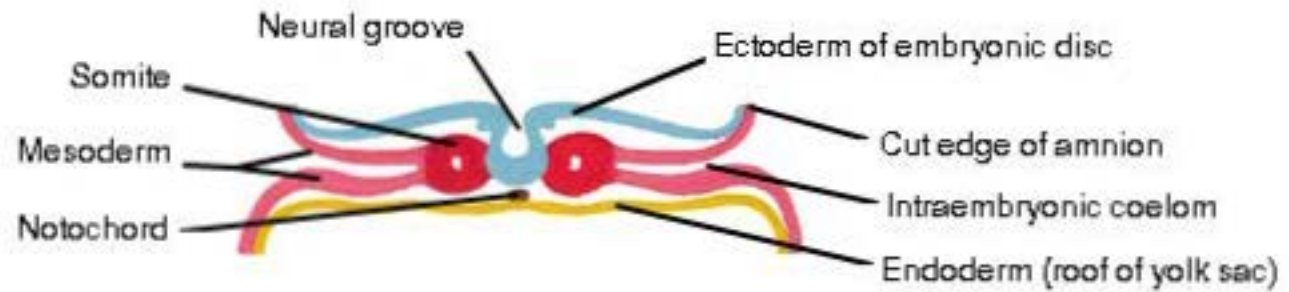


# Muscular System: Primordia

## Differentiation of somites into myotomes, sclerotomes, and dermatomes

### Cross section of human embryos

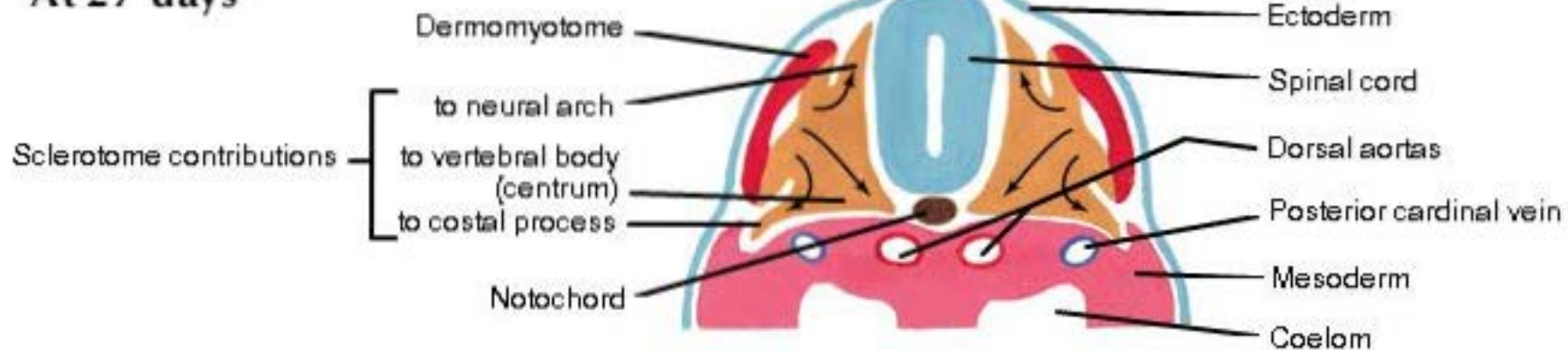
At 19 days



At 22 days

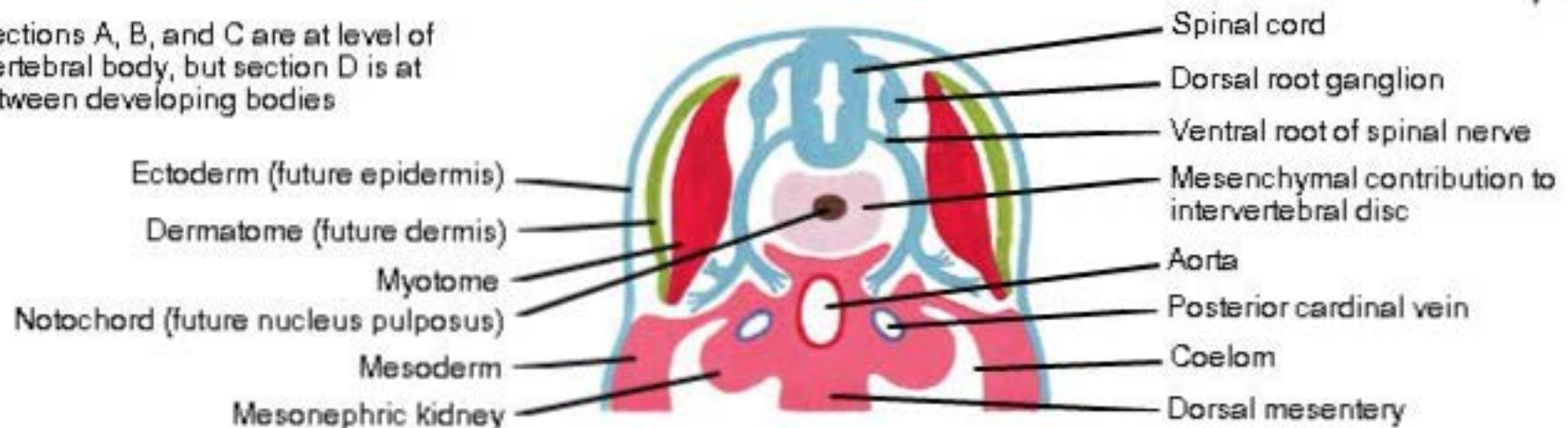


At 27 days



At 30 days

Note: Sections A, B, and C are at level of future vertebral body, but section D is at level between developing bodies

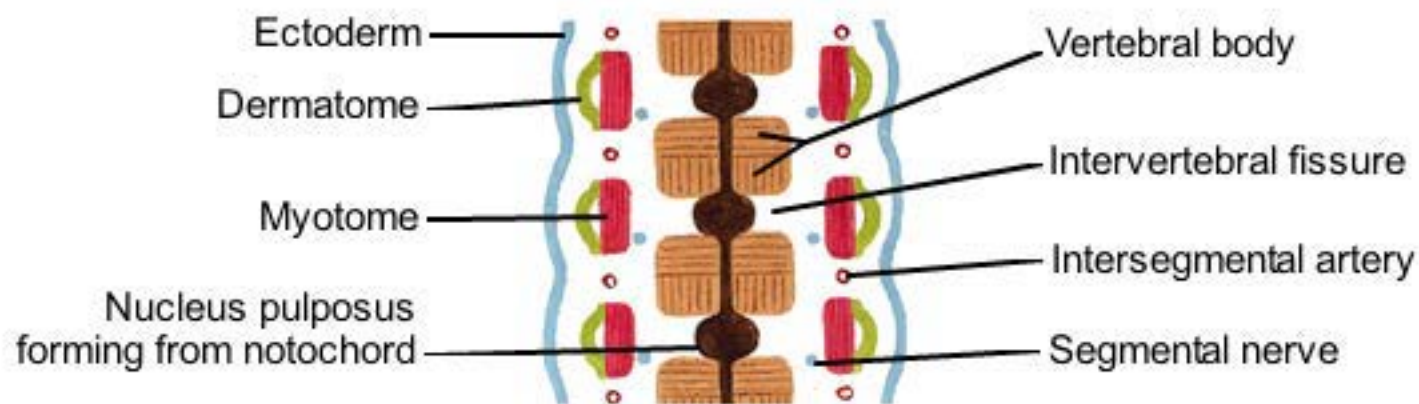
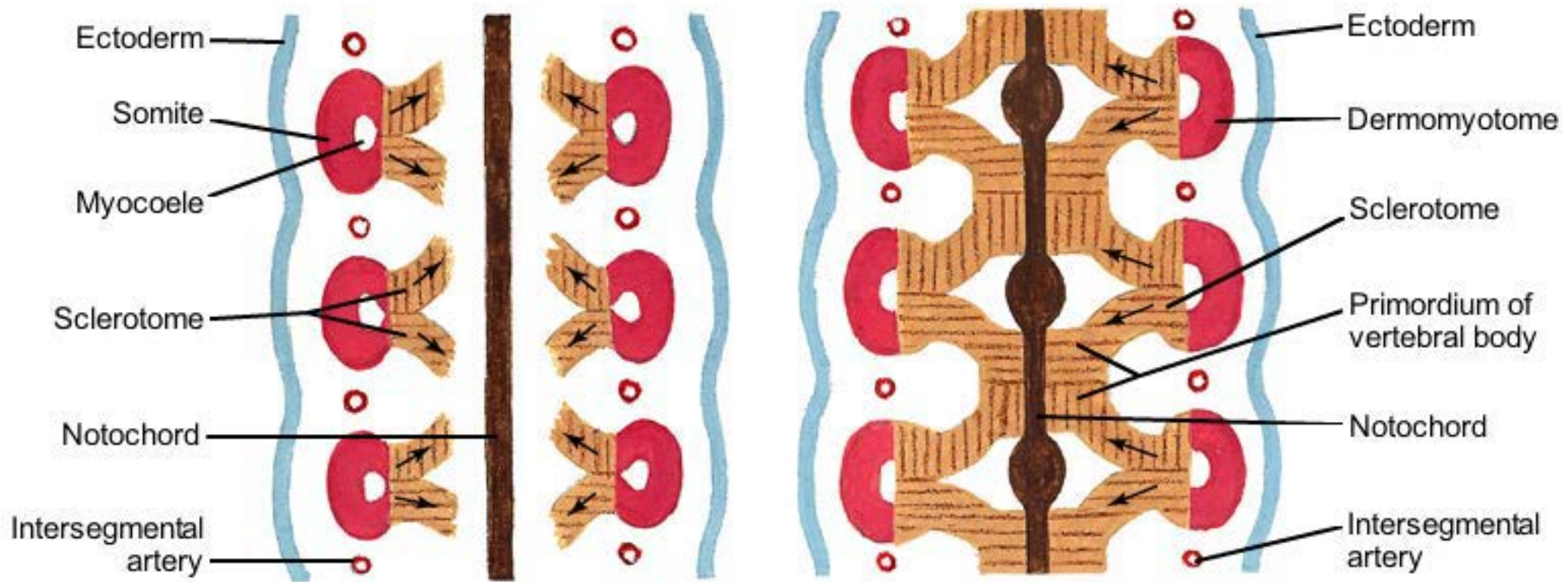


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# Muscle and Vertebral Column Segmentation

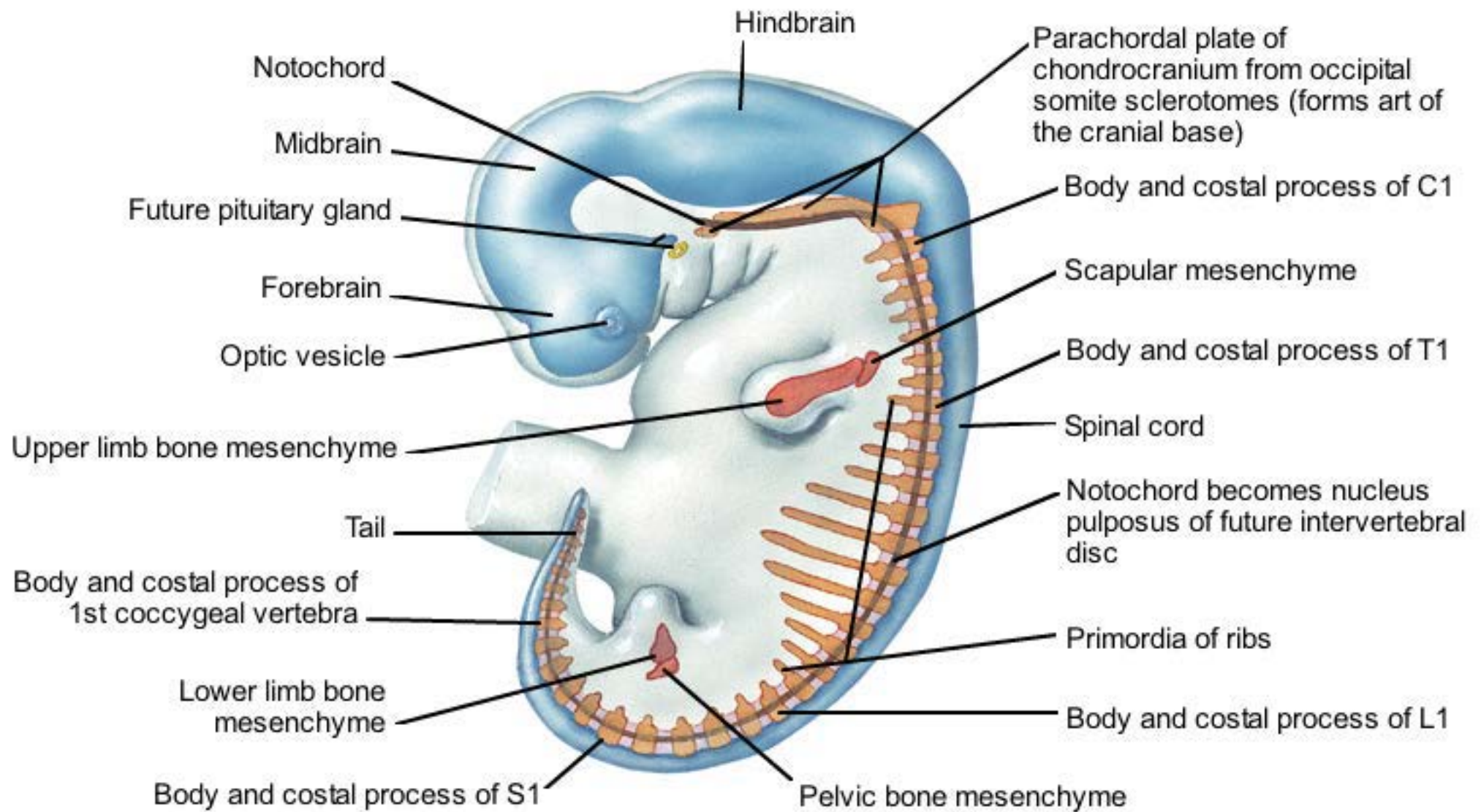
Progressive stages in formation of vertebral column, dermatomes, and myotomes



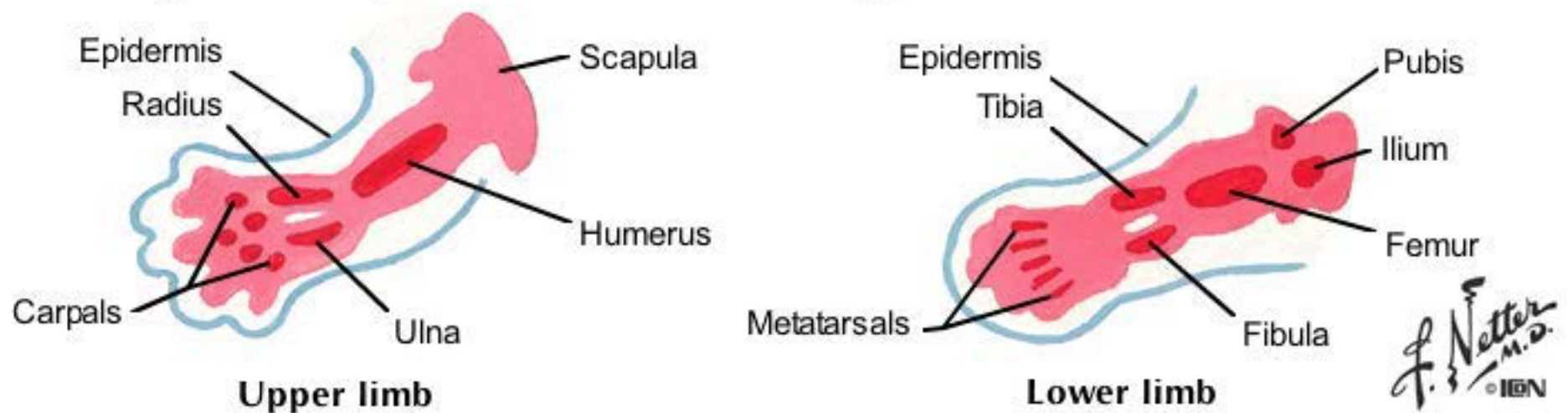


# Mesenchymal Primordia and 5 and 6 Weeks

## Mesenchymal precartilaginous primordia of axial and appendicular skeletons at 5 weeks



## Precartilaginous mesenchymal cell condensations of appendicular skeleton at 6th week

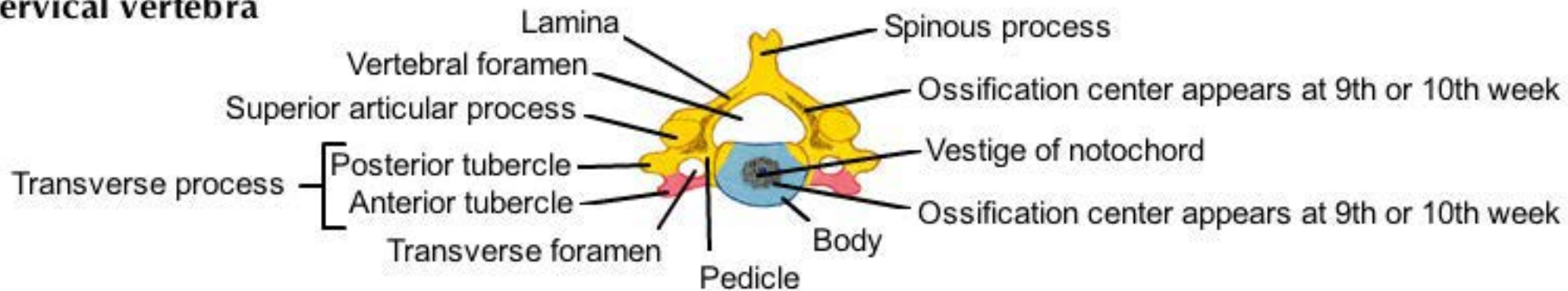




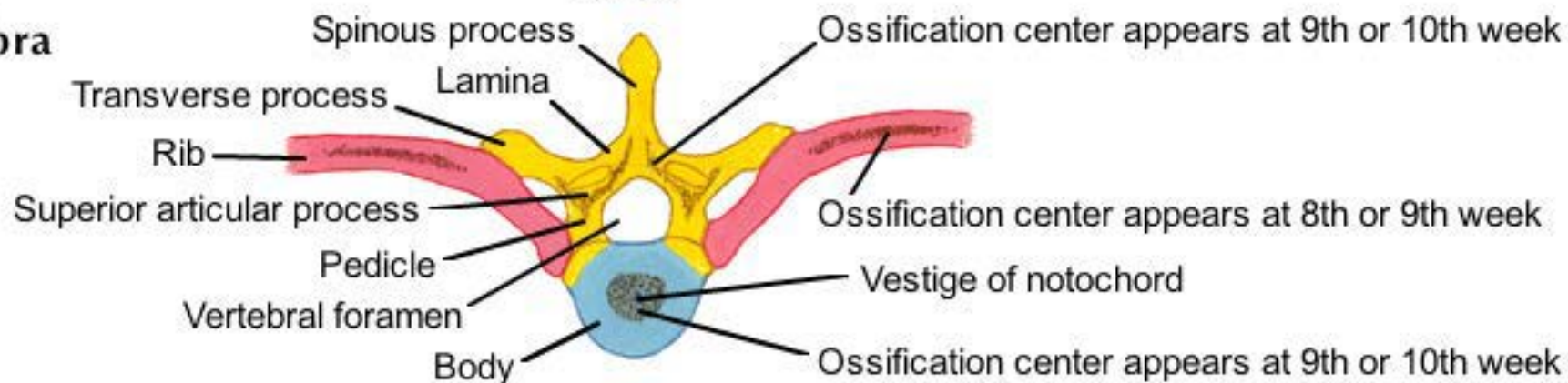
# Ossification of the Vertebral Column

Fate of body, costal process, and neural arch components of vertebral column, with sites and time of appearance of ossification centers

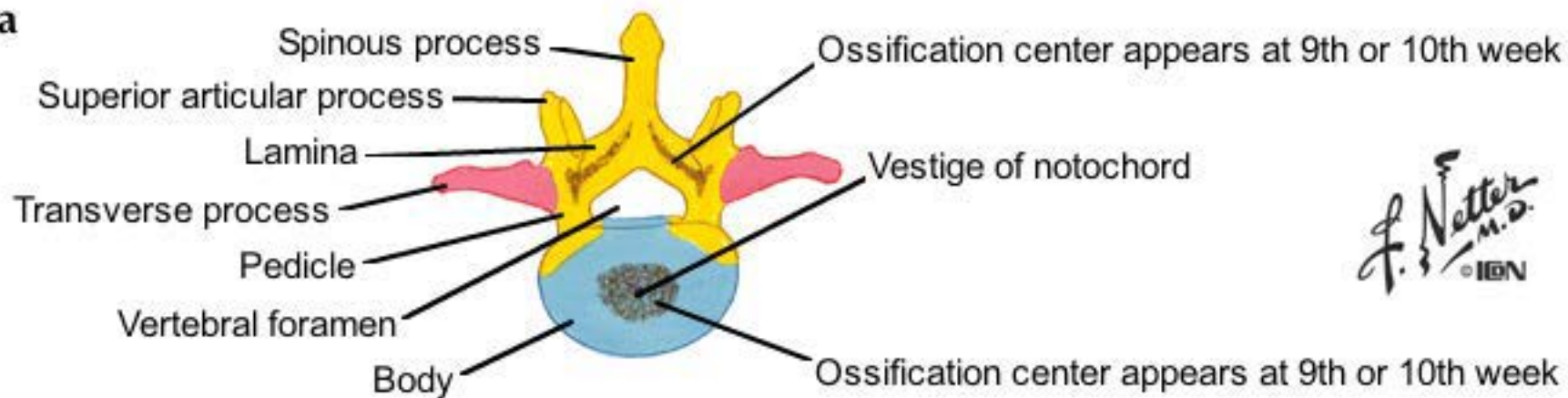
## Cervical vertebra



## Thoracic vertebra

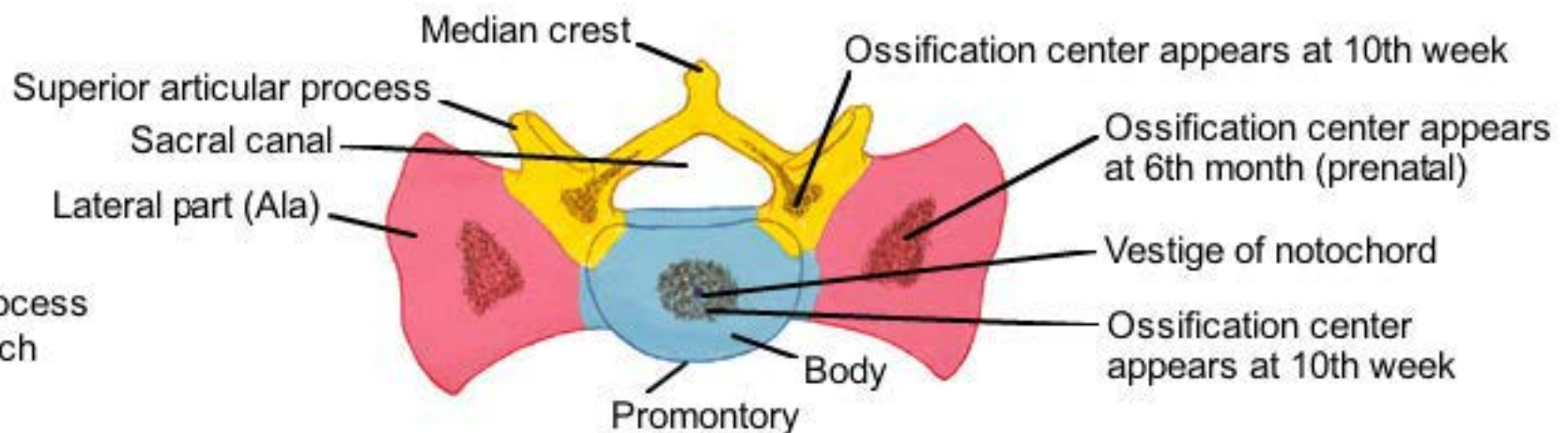


## Lumbar vertebra



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## Sacrum



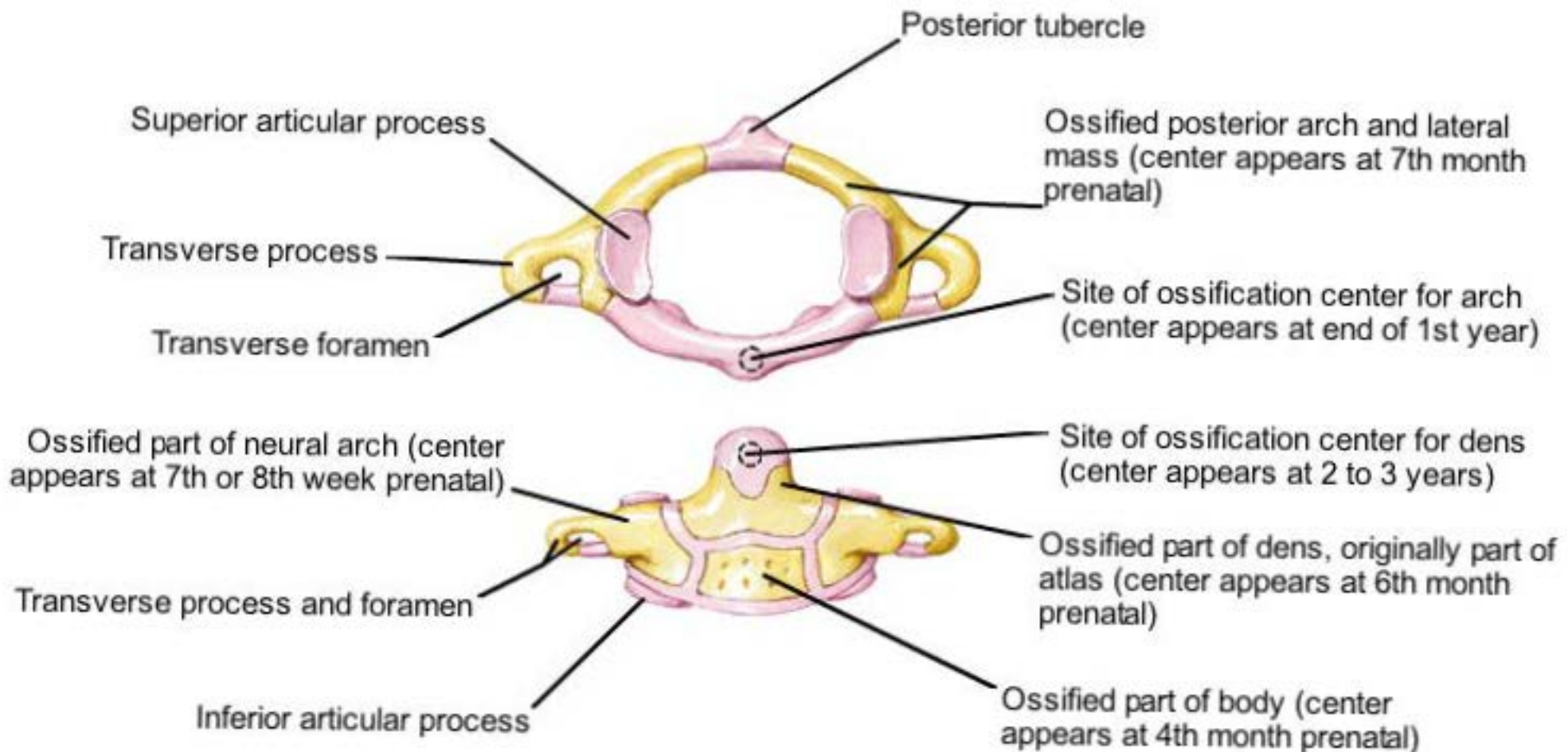
### KEY

- Body
- Costal process
- Neural arch

# Development of the Atlas, Axis, Ribs, and Sternum

First and second cervical vertebrae at birth

## A. 1st cervical vertebra (atlas) (superior view)



## B. 2nd cervical vertebra (axis) (anterior view)

### KEY

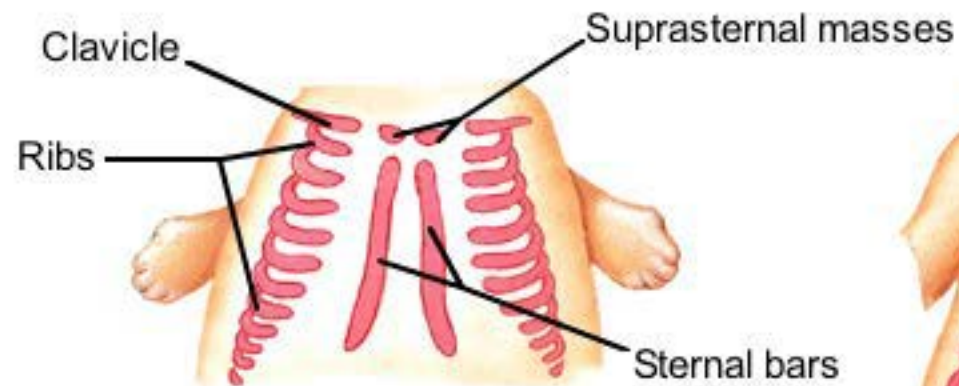




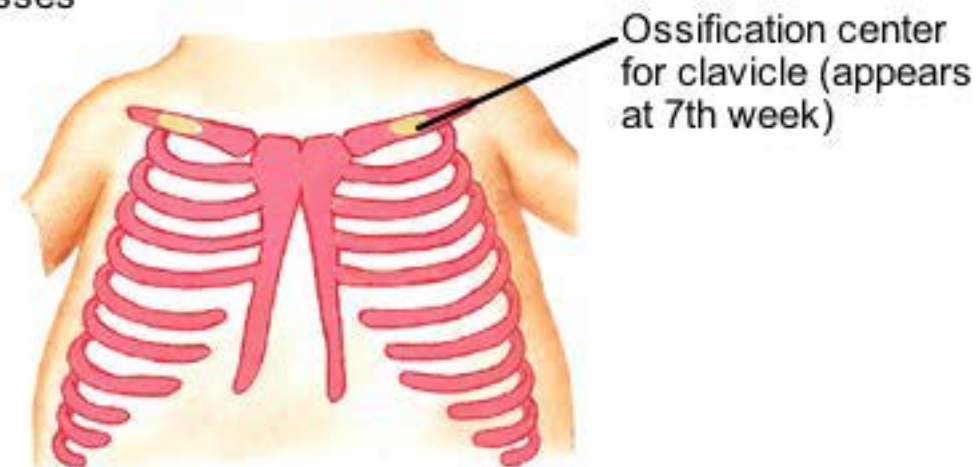
# Development of the Atlas, Axis, Ribs, and Sternum

## Development of sternum

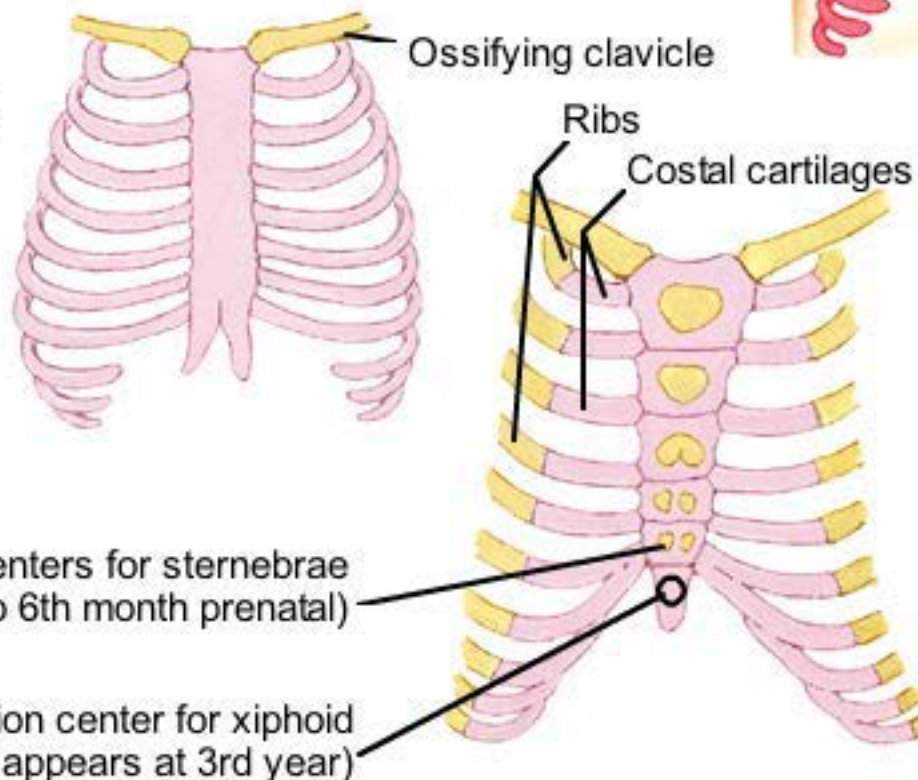
### A. Early mesenchymal stage (6 weeks)



### B. Late mesenchymal stage (8 weeks)



### C. Cartilage stage (9 weeks)

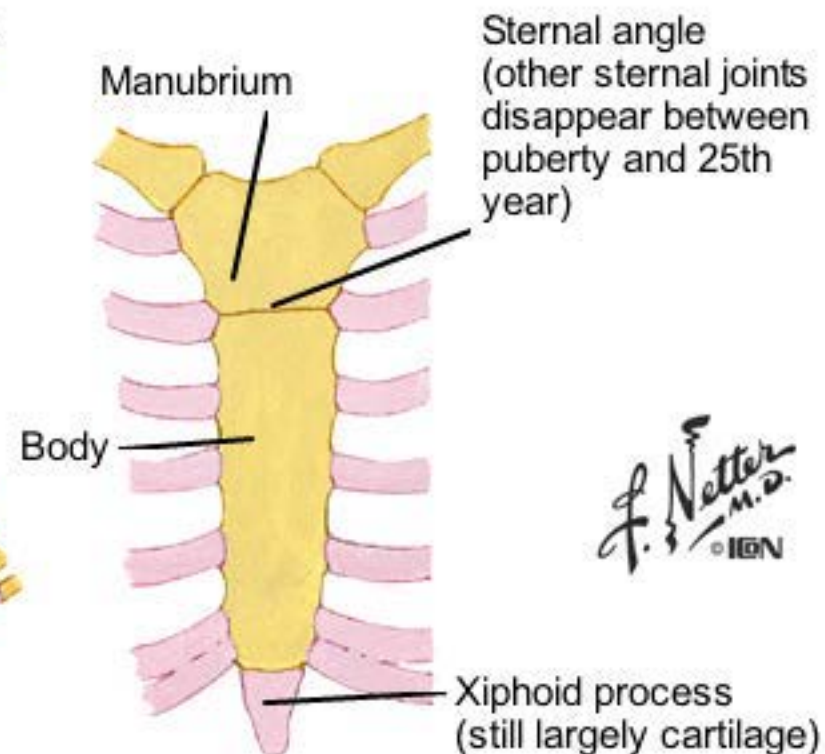


Ossification centers for sternebrae (appear at 5th to 6th month prenatal)

Site of ossification center for xiphoid process (center appears at 3rd year)

### D. At birth

#### KEY

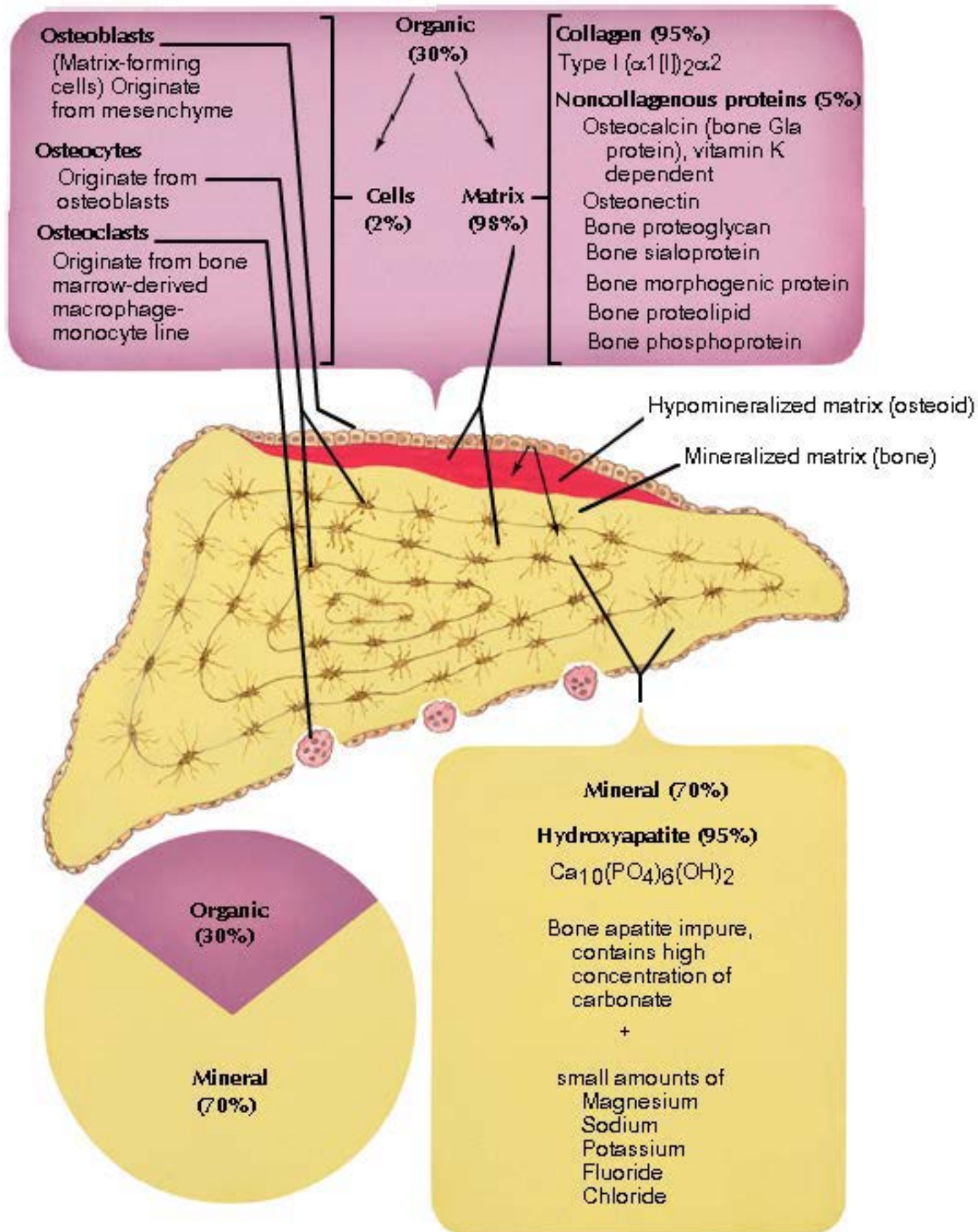


### E. Young adulthood

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# Bone Cells and Bone Deposition

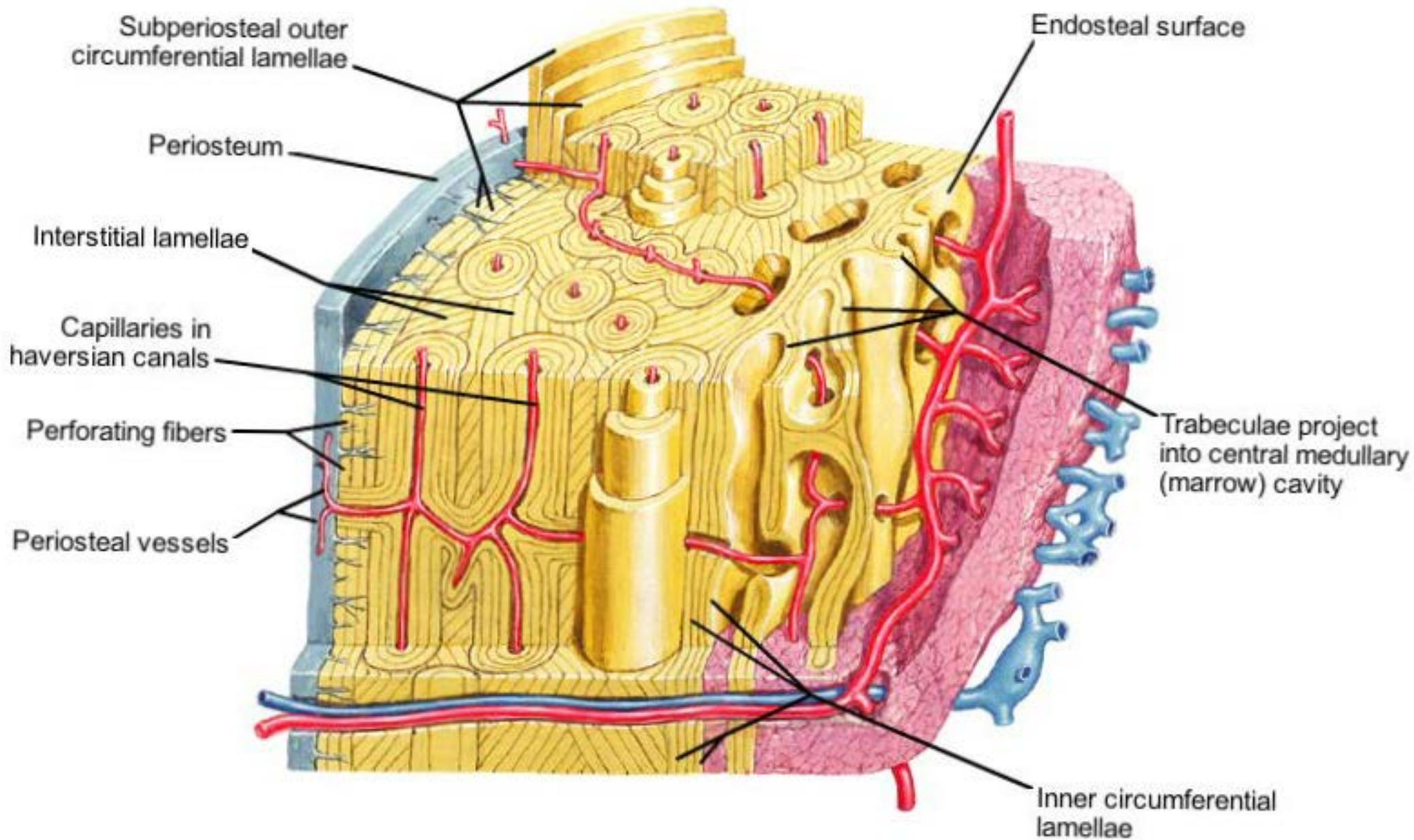
## Composition of bone





# Histology of Bone

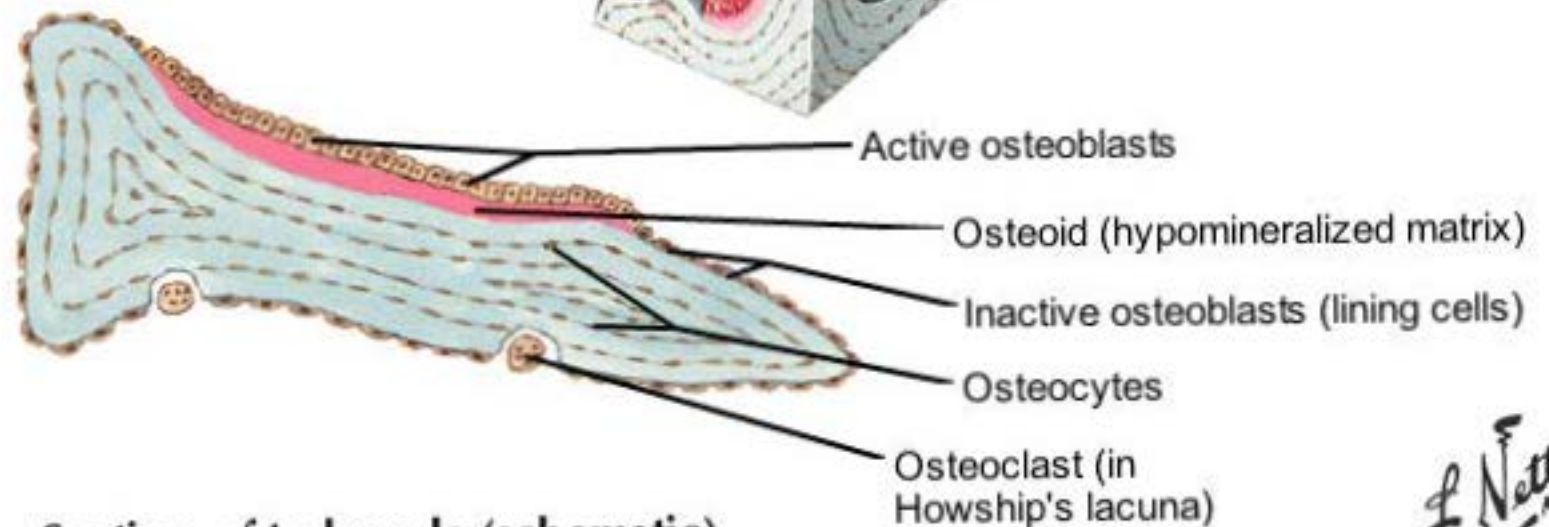
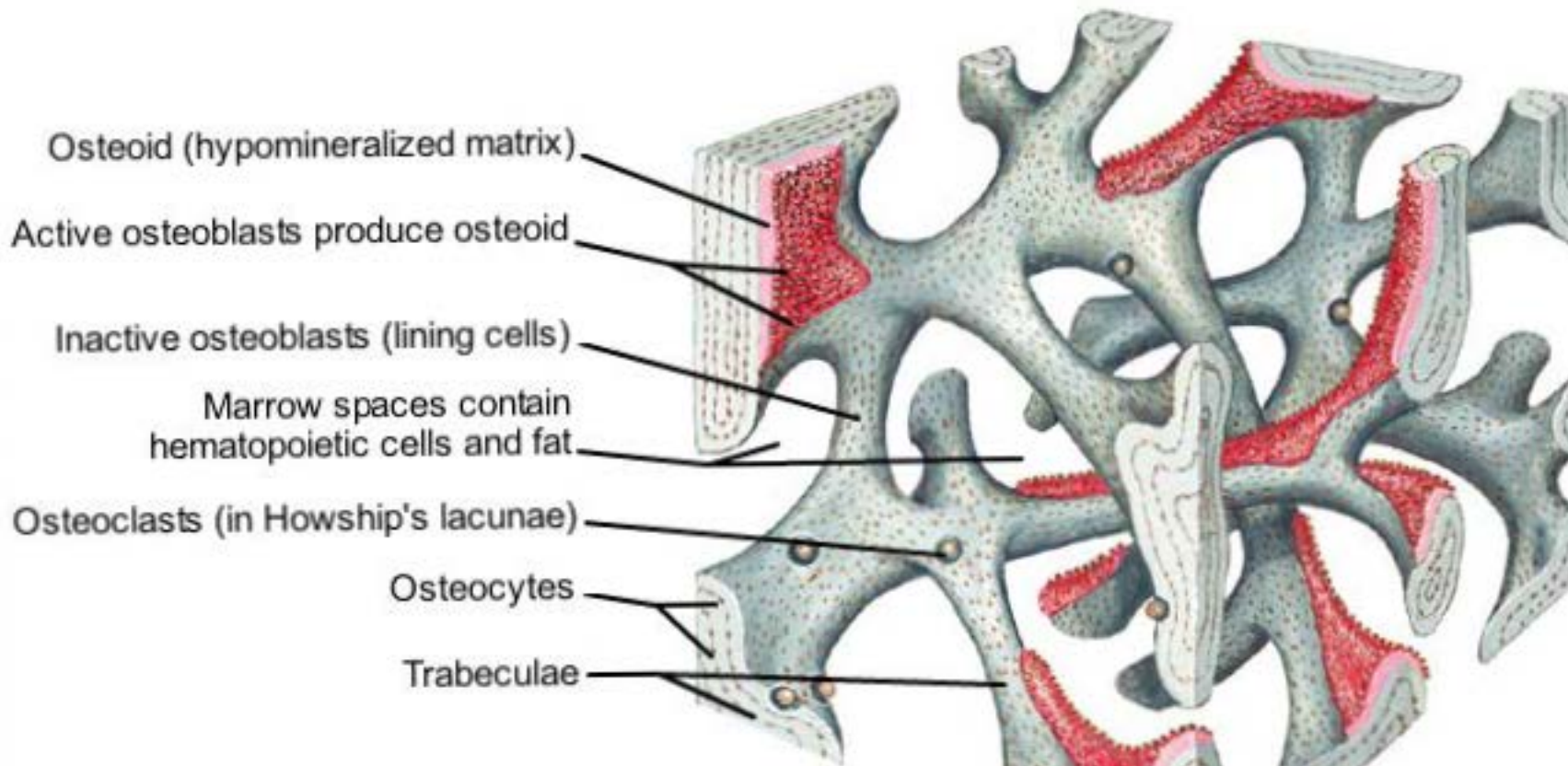
## Cortical (compact) bone



# Histology of Bone

## Trabecular bone (schematic)

On cut surfaces (as in sections), trabeculae may appear as discontinuous spicules



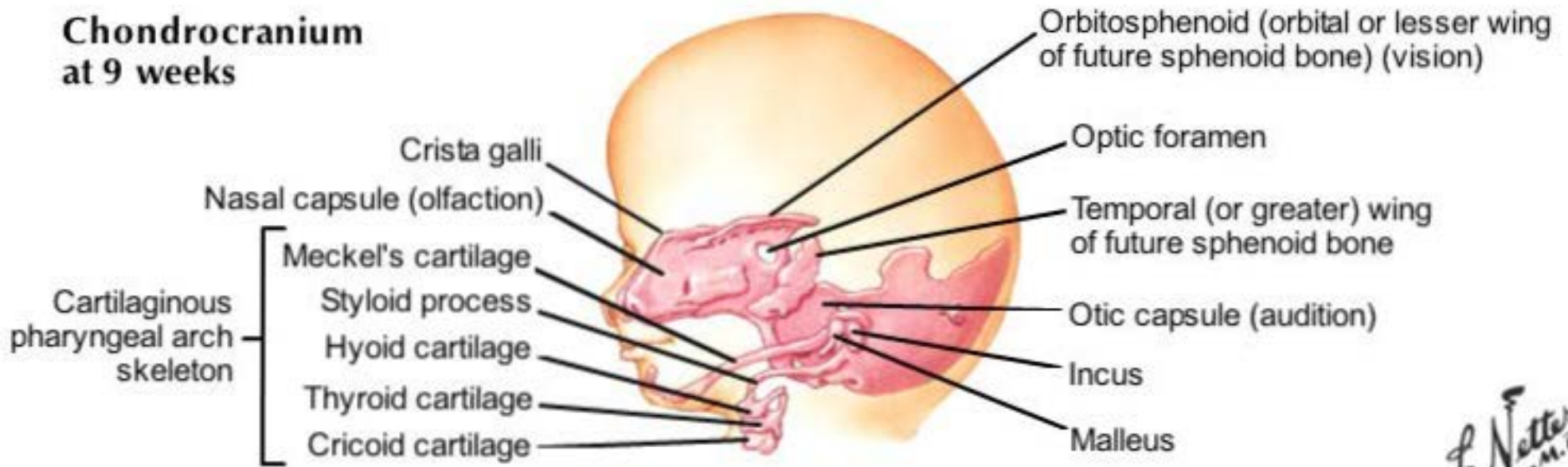
## Section of trabecula (schematic)



# Membrane Bone and Skull Development

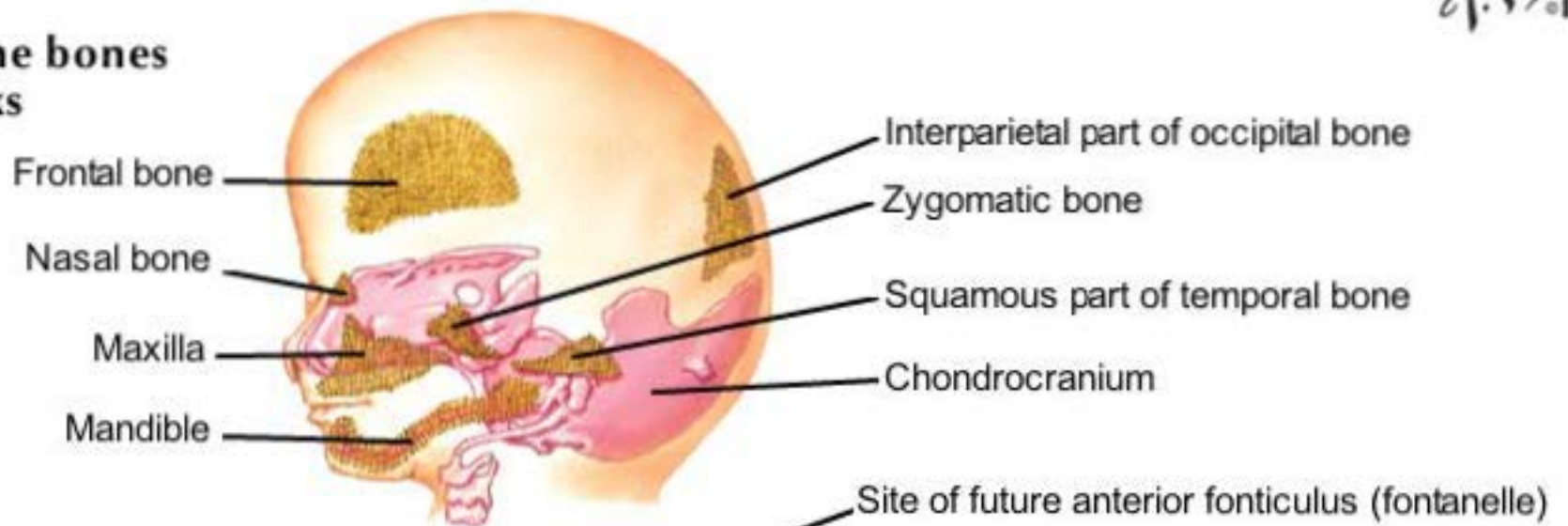
## Early development of skull

### Chondrocranium at 9 weeks

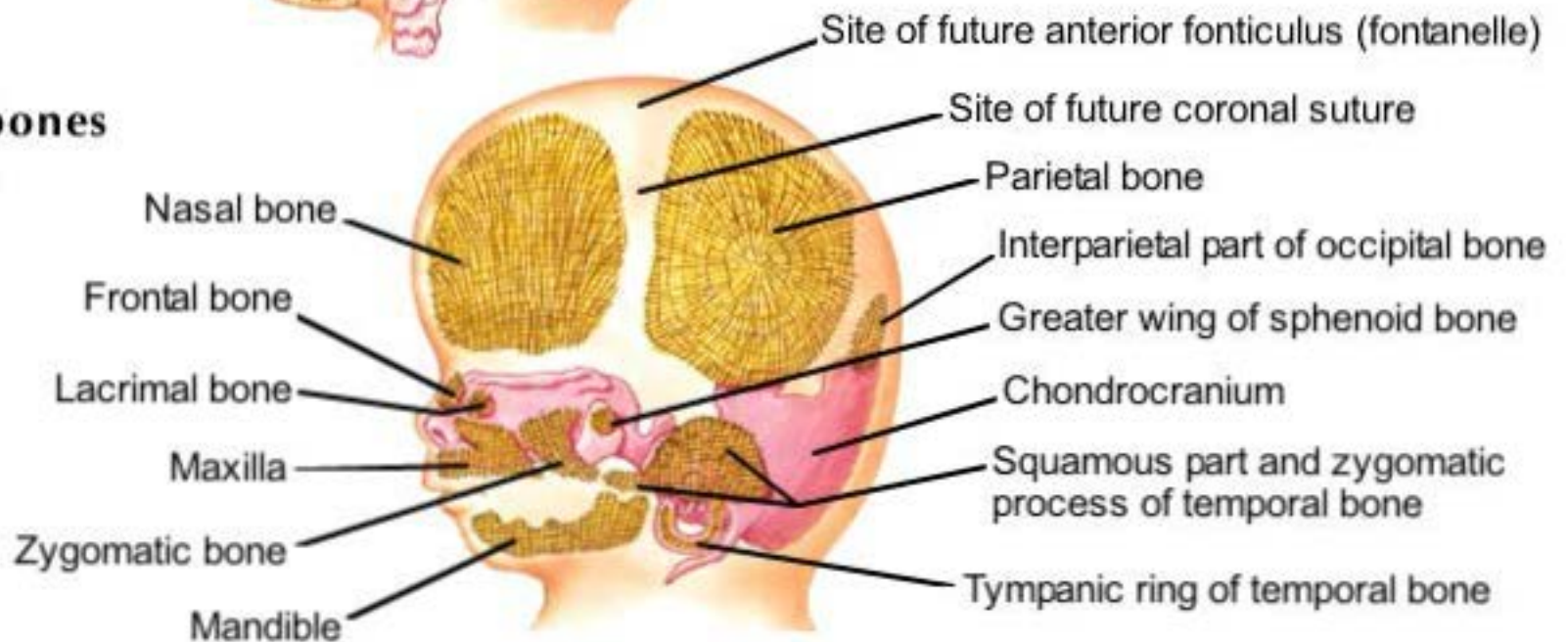


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### Membrane bones at 9 weeks



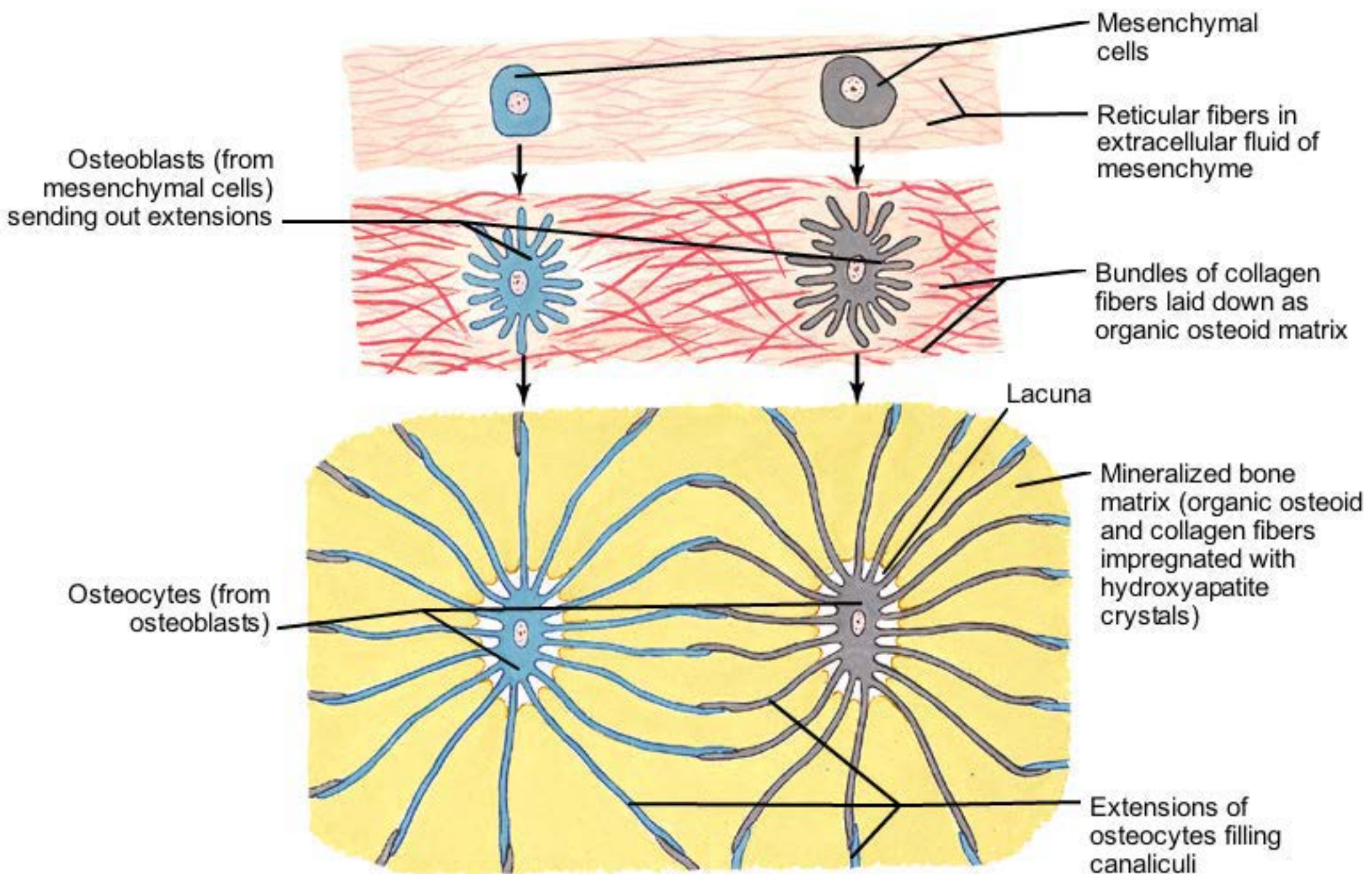
### Membrane bones at 12 weeks





# Bone Development in Mesenchyme

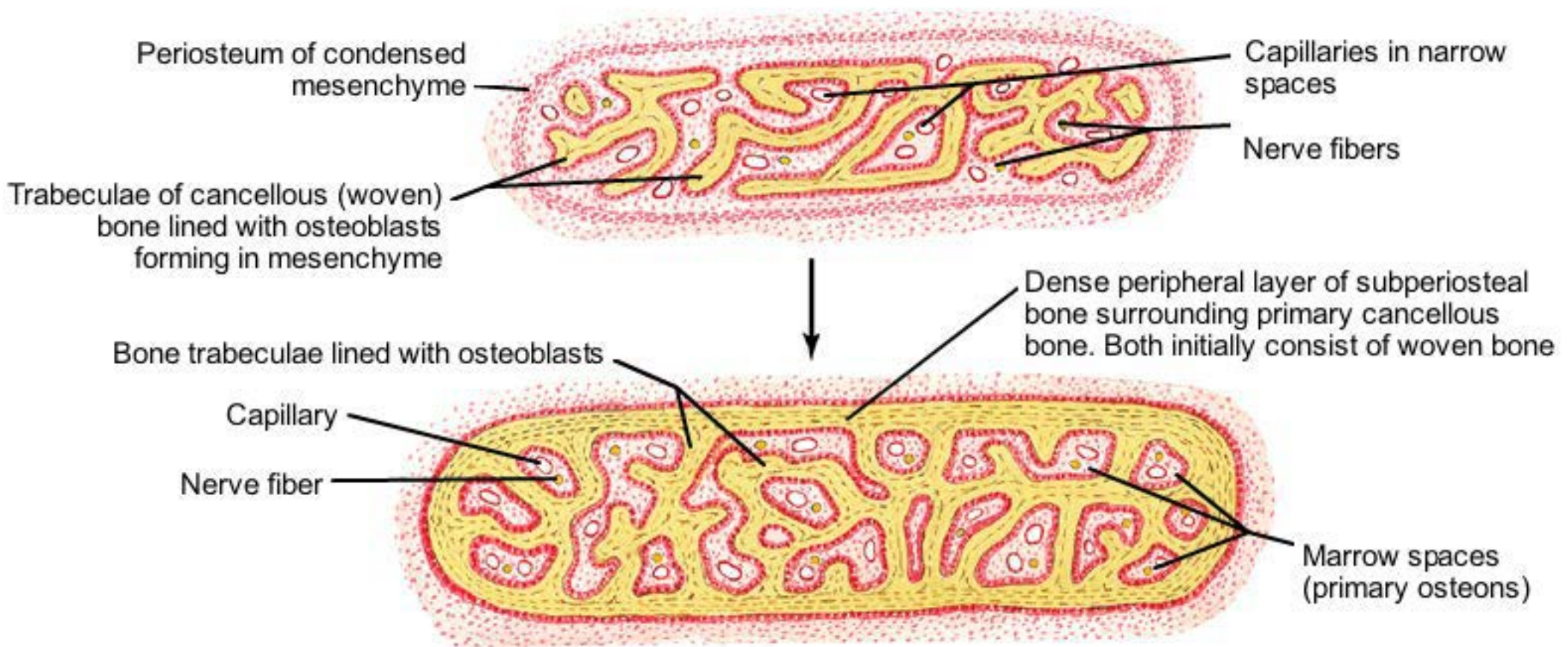
## Initial bone formation in mesenchyme





# Bone Development in Mesenchyme

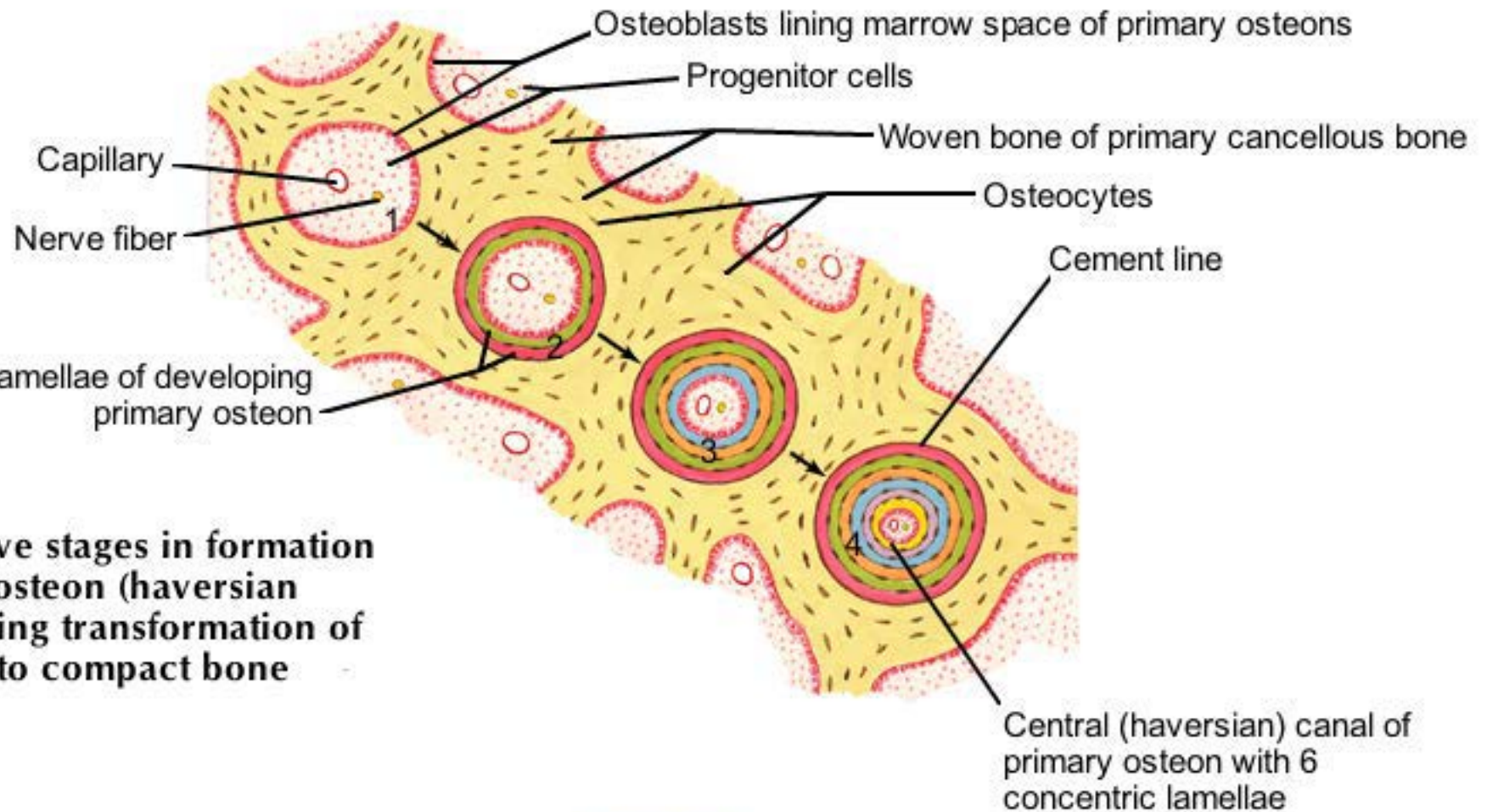
## Early stages of flat (membrane or dermal) bone formation



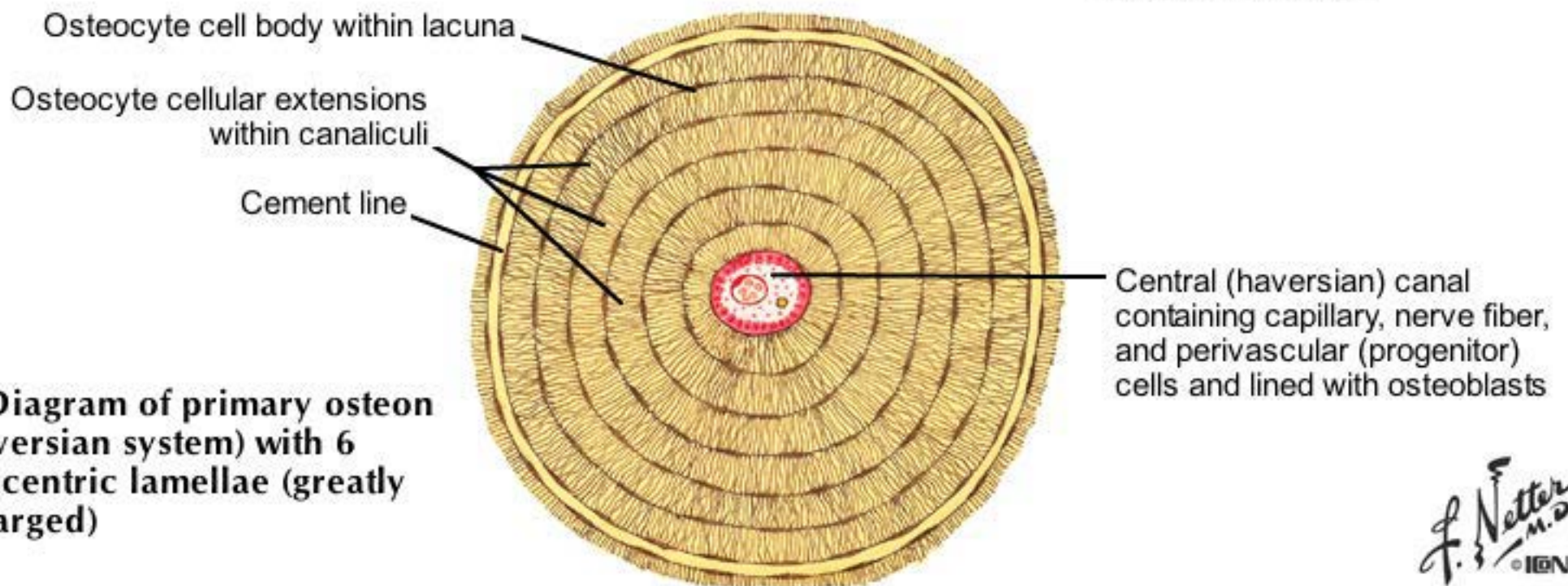


# Osteon Formation

## Primary osteon formation in mesenchymal bone development



**A. Successive stages in formation of primary osteon (haversian system) during transformation of cancellous to compact bone (schematic)**

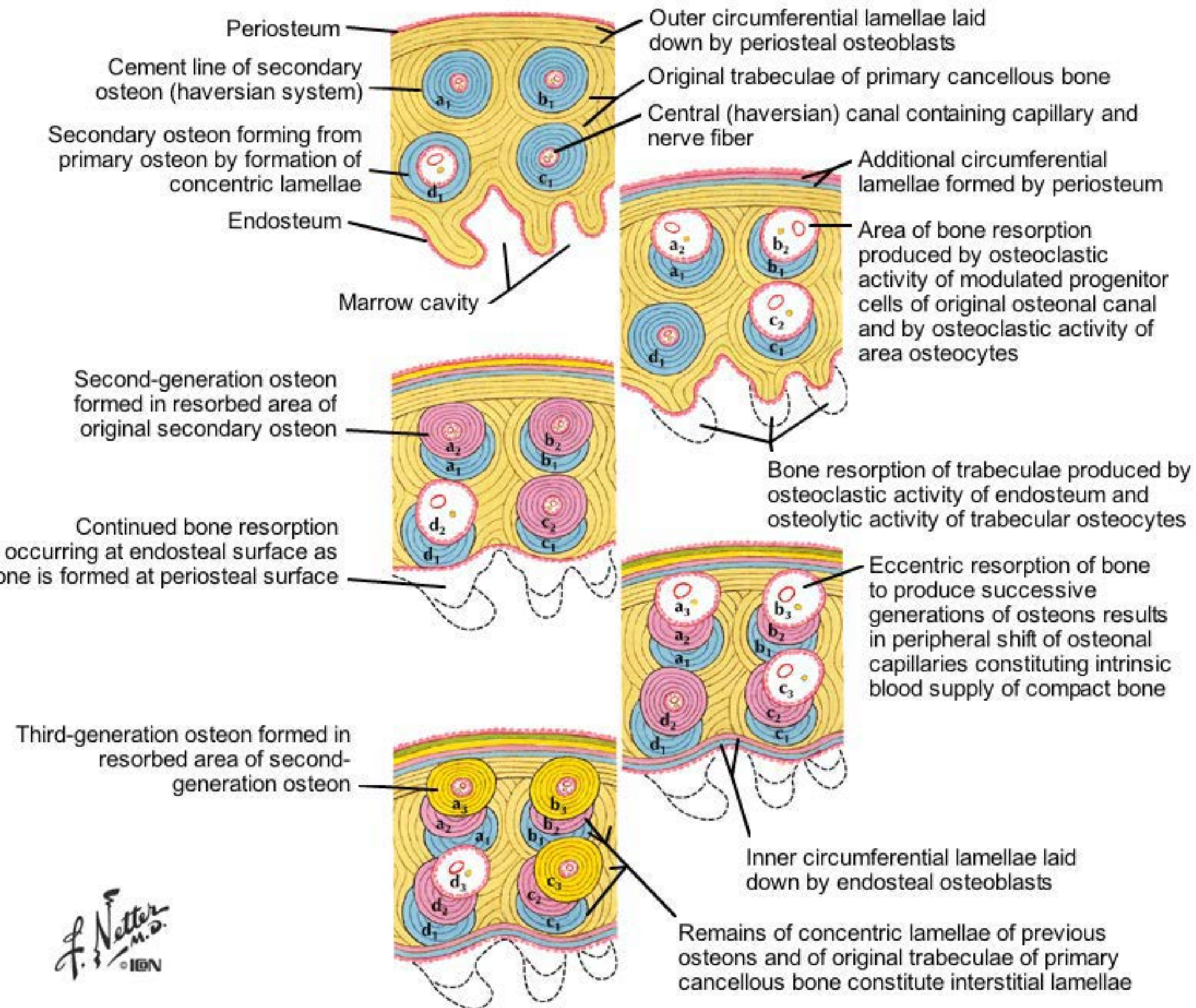


**B. Diagram of primary osteon (haversian system) with 6 concentric lamellae (greatly enlarged)**



# Compact Bone Development and Remodeling

## Growth in width of a bone and osteon remodeling



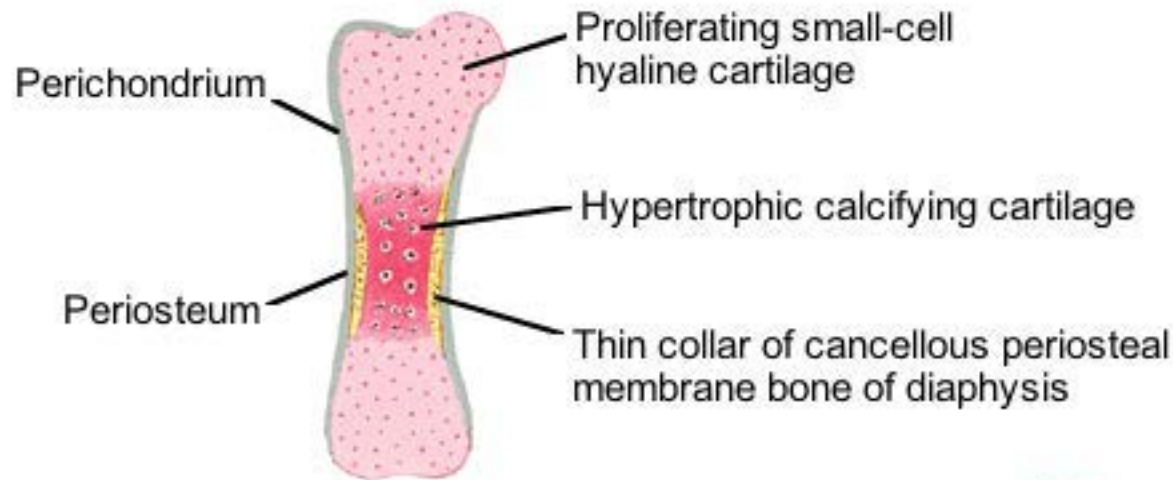


# Endochondral Ossification in a Long Bone

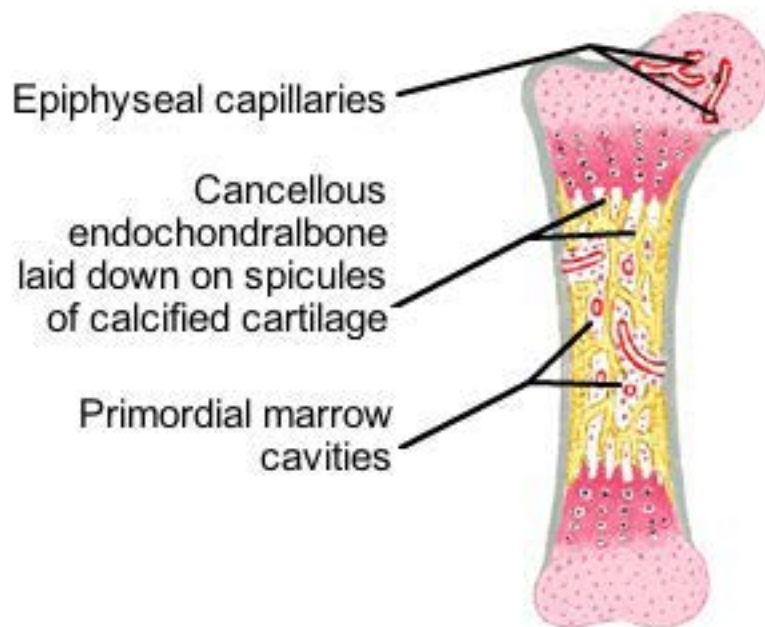
Growth and ossification of long bones (humerus, midfrontal sections)

Canals, containing capillaries, periosteal mesenchymal cells, and osteoblasts, passing through periosteal bone into calcified cartilage (primary ossification center)

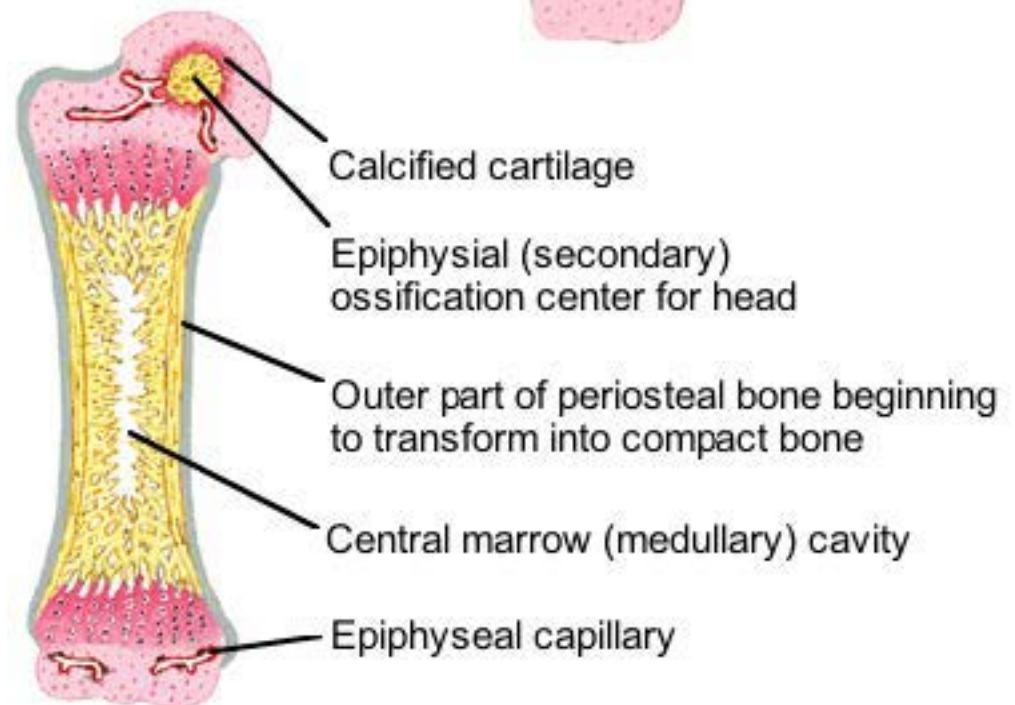
**A. At 8 weeks**



**B. At 9 weeks**



**C. At 10 weeks**



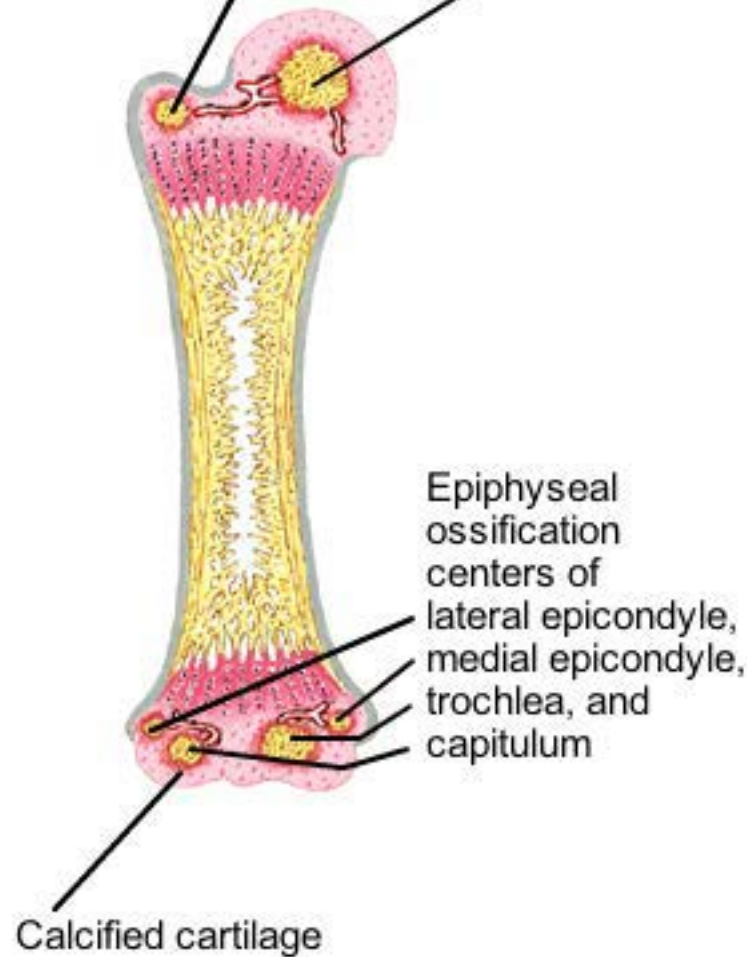
**D. At birth**



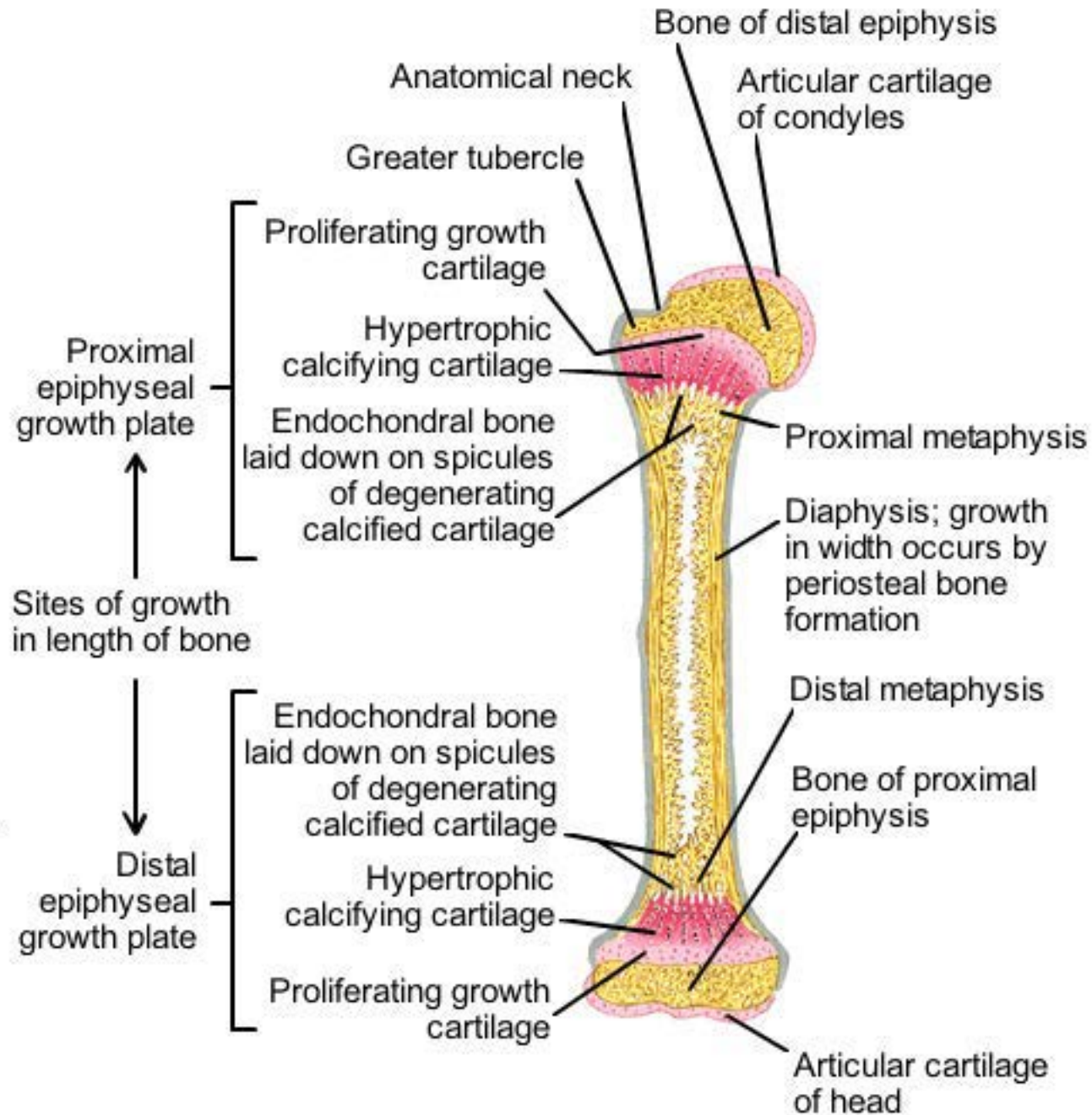
# Endochondral Ossification in a Long Bone

## Growth and ossification of long bones (humerus, midfrontal sections)

Epiphyseal ossification centers for head and greater tubercle



E. At 5 years

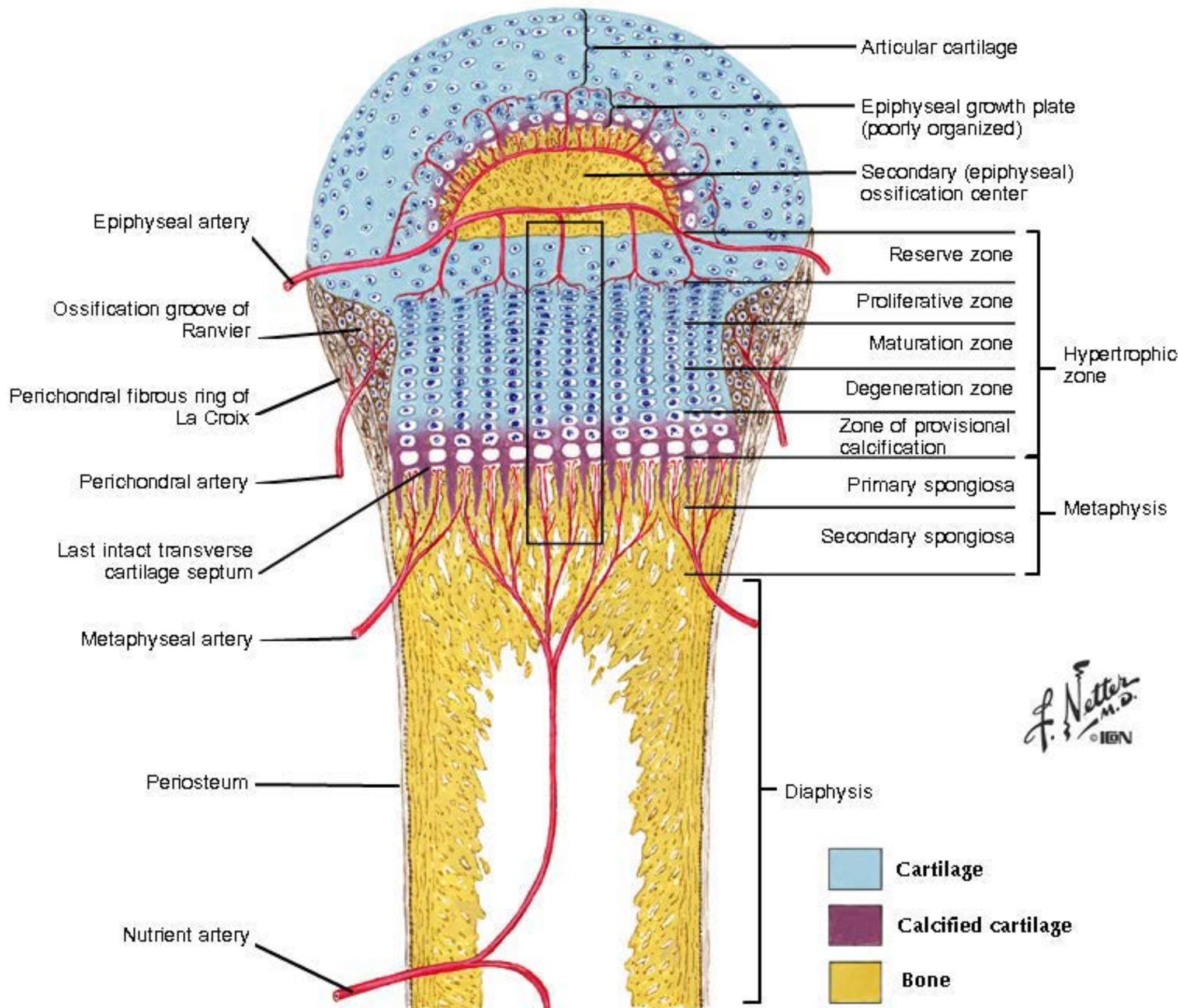


F. At 10 years



# Epiphyseal Growth Plate

## Close-up view of developing epiphysis and epiphyseal growth plate



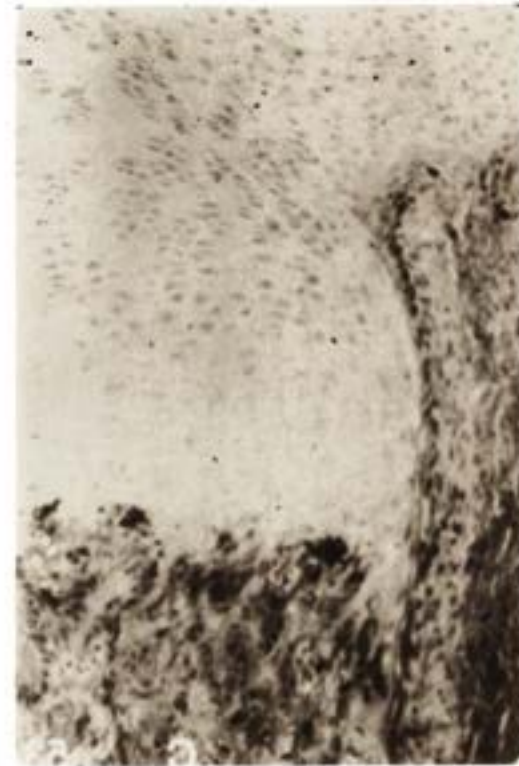
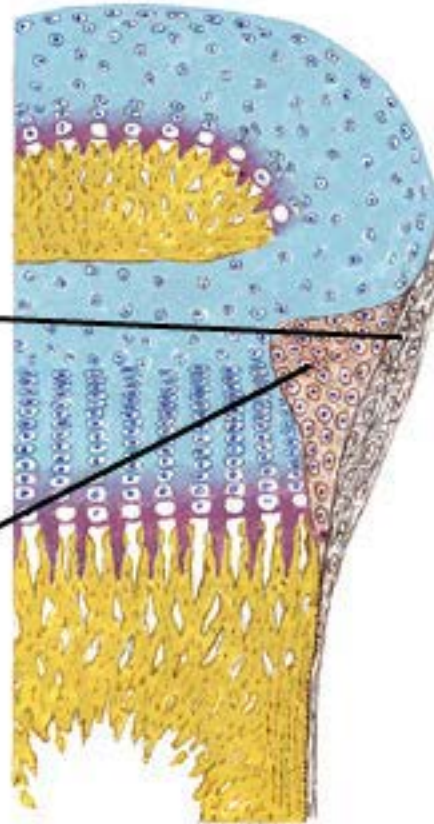


# Peripheral Cartilage Function in the Epiphysis

## Peripheral fibrocartilaginous element of growth plate

Perichondral fibrous ring of La Croix (provides support)

Ossification groove of Ranvier (provides cells for growth in width)

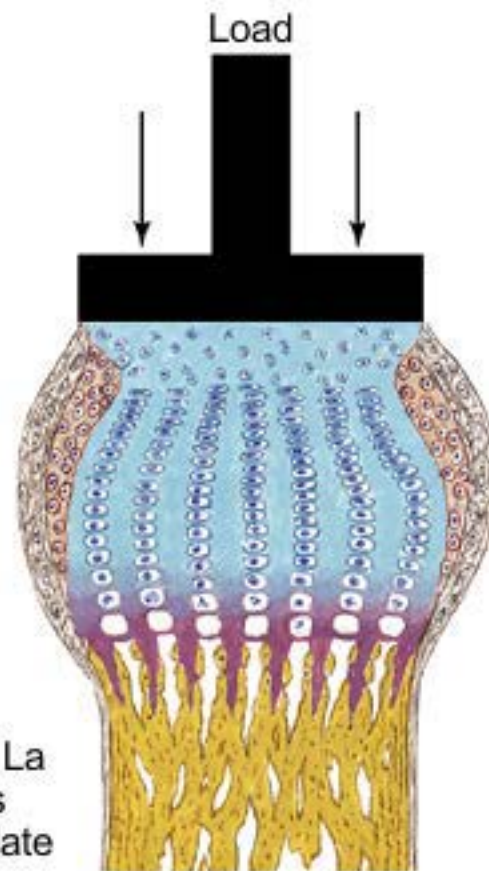


Microscopic section (H&E) corresponds generally to illustration at left

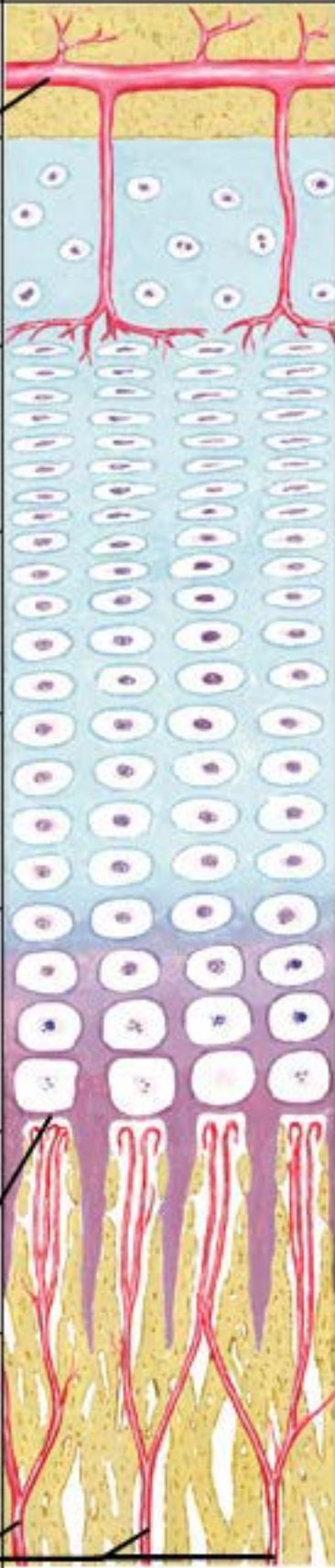


High-power section shows cells of ossification groove of Ranvier apparently "flowing" into cartilage at level of reserve zone, thus contributing to growth in width of growth plate. Note presence of arterioles (cut-in section)

Illustration of how perichondral fibrous ring of La Croix acts as limiting membrane and provides mechanical support to cartilaginous growth plate

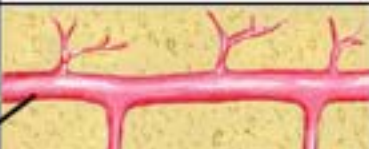


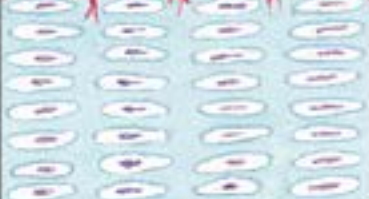


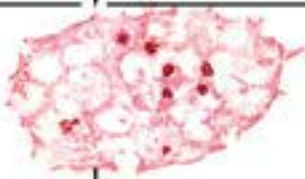


# Epiphyseal Growth Plate


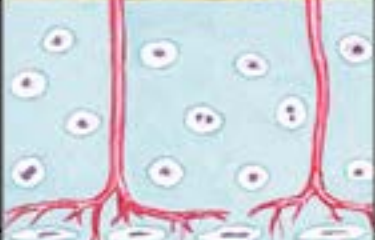










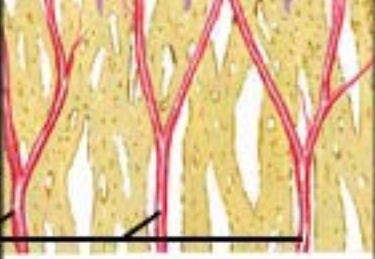
Zones Structures	Histology	Functions	Blood supply	PO <sub>2</sub>	
Secondary bony epiphysis Epiphyseal artery					
Reserve zone		Matrix production Storage	Vessels pass through, do not supply this zone	Poor (low)	
Proliferative zone		Matrix production Cellular proliferation (longitudinal growth)	Excellent	Excellent	
Hypertrophic zone		Maturation zone	Preparation of matrix for calcification	Progressive decrease	Poor (low)
					Progressive decrease
		Degenerative zone			
Zone of provisional calcification		Calcification of matrix	Nil	Poor (very low)	
Metaphysis		Primary spongiosa Last intact transverse septum	Vascular invasion and resorption of transverse septa Bone formation	Closed capillary loops Good	Poor Good
			Secondary spongiosa Branches of metaphyseal and nutrient arteries	Remodeling Internal: removal of cartilage bars, replace- ment of fiber bone with lamellar bone External: funnelization	Excellent



# Epiphyseal Growth Plate

Zones Structures	Histology	Cell (chondrocyte) health	Cell respiration	Cell glycogen
Secondary bony epiphysis Epiphyseal artery				
Reserve zone		 Good, active. Much endoplasmic reticulum, vacuoles, mitochondria	Anaerobic	High concentration
Proliferative zone		 Excellent. Much endoplasmic reticulum, ribosomes, mitochondria. Intact cell membrane	Aerobic	High concentration (less than in above)
Hypertrophic zone	Maturation zone	 Still good	Progressive change to anaerobic	Glycogen consumed until depleted
	Degenerative zone	Progressive deterioration	Anaerobic glycolysis	
	Zone of provisional calcification	 Cell death	Anaerobic glycolysis	Nil
Metaphysis	Last intact transverse septum		Progressive reversion to aerobic	?
	Primary spongiosa			
	Secondary spongiosa Branches of metaphyseal and nutrient arteries		Aerobic	?








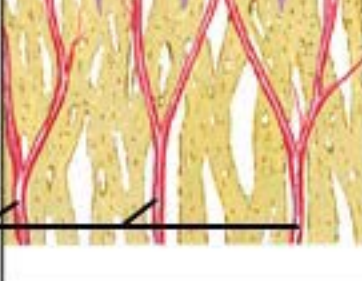
# Epiphyseal Growth Plate

Zones Structures		Histology	Cell (chondrocyte) health	Cell respiration	Cell glycogen
Secondary bony epiphysis					
Reserve zone			 Good, active. Much endoplasmic reticulum, vacuoles, mitochondria	Anaerobic	High concentration
Proliferative zone			 Excellent. Much endoplasmic reticulum, ribosomes, mitochondria. Intact cell membrane	Aerobic	High concentration (less than in above)
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	Degenerative zone		Progressive deterioration	Anaerobic glycolysis	
	Zone of provisional calcification		 Cell death	Anaerobic glycolysis	Nil
Metaphysis	Last intact transverse septum			Progressive reversion to aerobic	?
	Primary spongiosa				
	Secondary spongiosa			Aerobic	?

*F. Netter M.D.*  
© IGV



# Epiphyseal Growth Plate

Zones Structures	Histology	Exemplary diseases	Defect (if known)
<b>Secondary bony epiphysis</b> Epiphyseal artery			
<b>Reserve zone</b>		Diastrophic dwarfism ..... (also, defects in other zones) Pseudoachondroplasia ..... (also, defects in other zones) Kniest syndrome ..... (also, defects in other zones)	Defective type II collagen synthesis Defective processing and transport of proteoglycans Defective processing of proteoglycans
<b>Proliferative zone</b>		Gigantism ..... Achondroplasia ..... Hypochondroplasia ..... Malnutrition, irradiation ..... injury, glucocorticoid excess	Increased cell proliferation (growth hormone increased) Deficiency of cell proliferation Less severe deficiency of cell proliferation Decreased cell proliferation and/or matrix synthesis
<b>Maturation zone</b>			
<b>Degenerative zone</b>		Mucopolysaccharidosis ..... (Morquio's syndrome, Hurler's syndrome)	Deficiencies of specific lysosomal acid hydrolases, with lysosomal storage of mucopolysaccharides
<b>Zone of provisional calcification</b>		Rickets, osteomalacia ..... also, defects in metaphysis)	Insufficiency of $\text{Ca}^{2+}$ and/or $\text{P}_i$ for normal calcification of matrix
<b>Primary spongiosa</b> Last intact transverse septum		Metaphyseal chondrodysplasia ..... (Jansen and Schmid types) Acute hematogenous osteomyelitis	Extension of hypertrophic cells into metaphysis Flourishing of bacteria due to sluggish circulation, low $\text{P}_{\text{O}_2}$ , reticuloendothelial deficiency
<b>Secondary spongiosa</b> Branches of metaphyseal and nutrient arteries		Osteopetrosis ..... Osteogenesis imperfecta ..... Scurvy ..... Metaphyseal dysplasia ..... (Pyle disease)	Abnormality of osteoclasts (internal remodeling) Abnormality of osteoblasts and collagen synthesis Inadequate collagen formation Abnormality of funnelization (external remodeling)

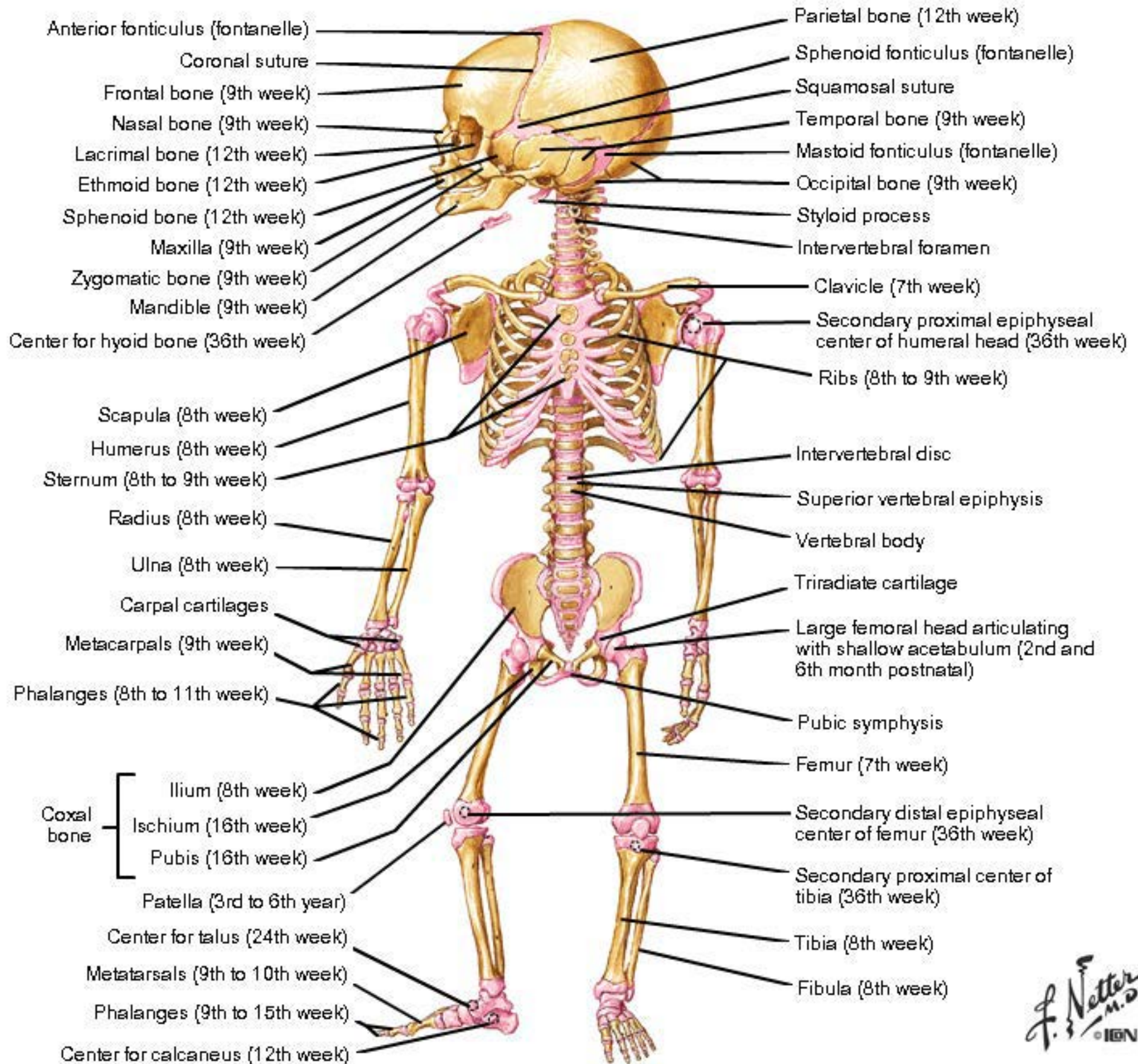
*F. Netter M.D.*  
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# Ossification in the Newborn Skeleton

## Skeleton of full-term newborn

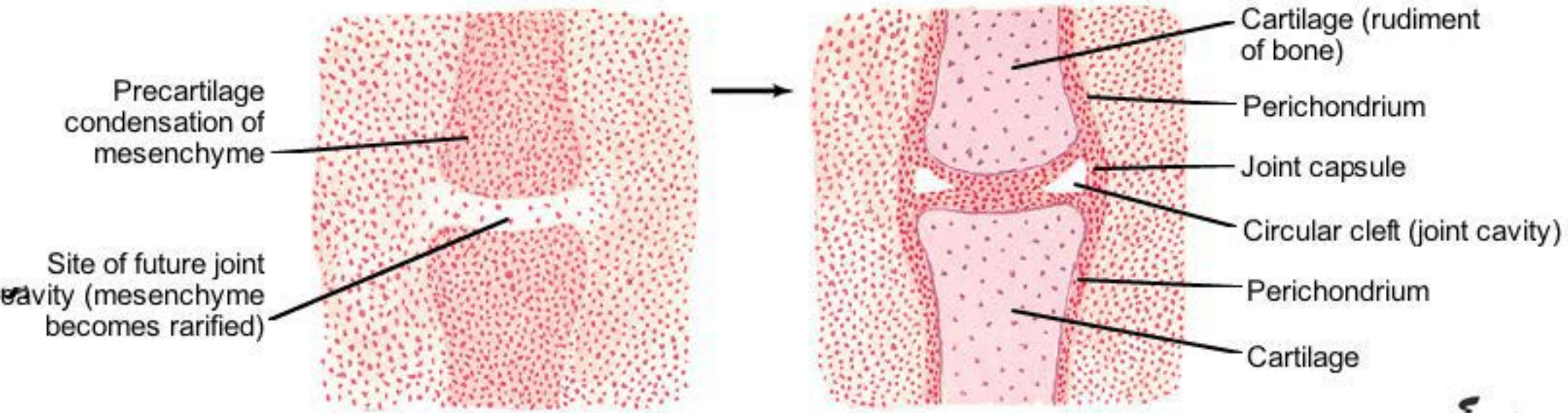
Time of appearance of ossification centers (primary unless otherwise indicated)



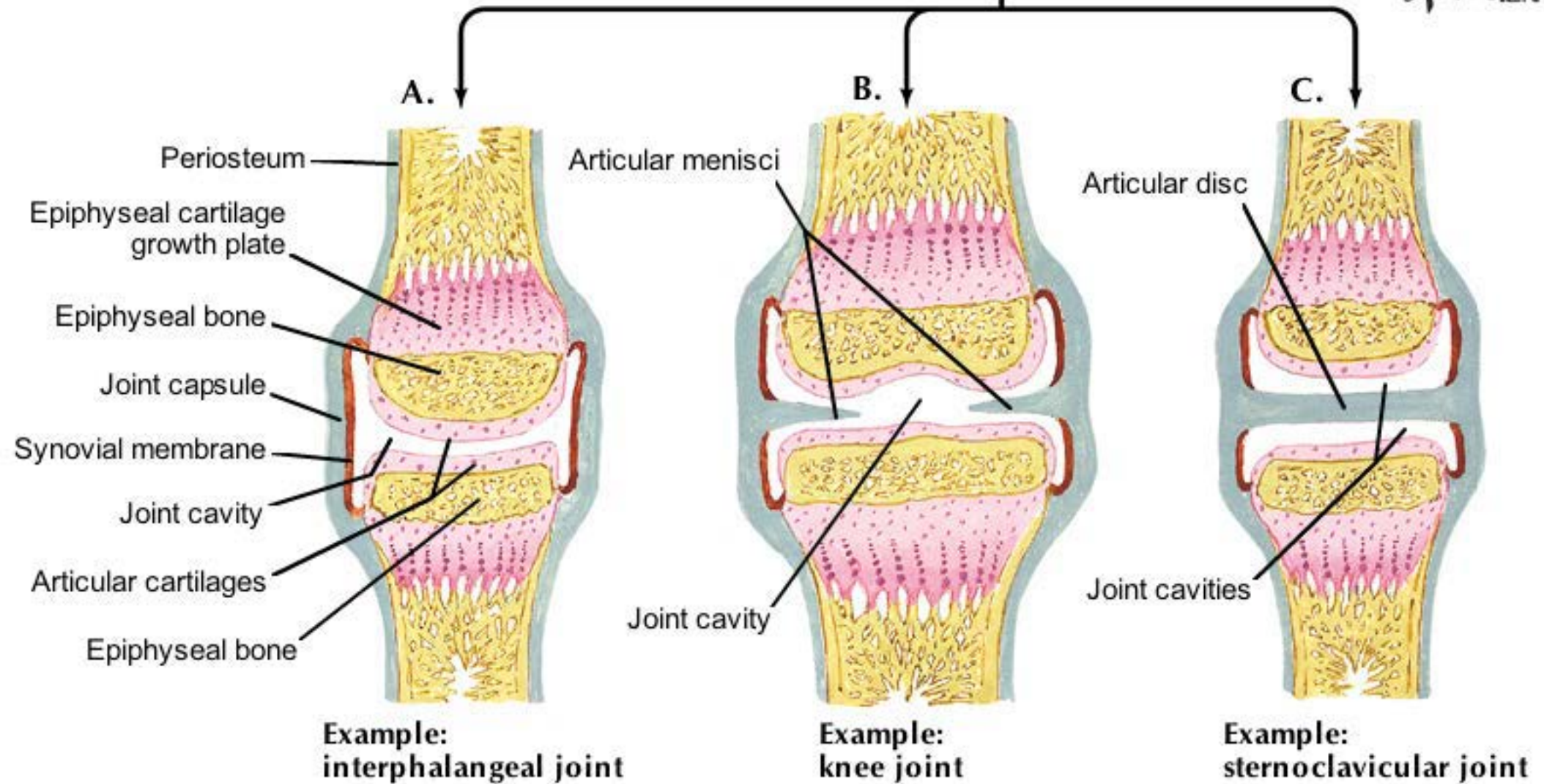


# Joint Development

## Development of three types of synovial joints



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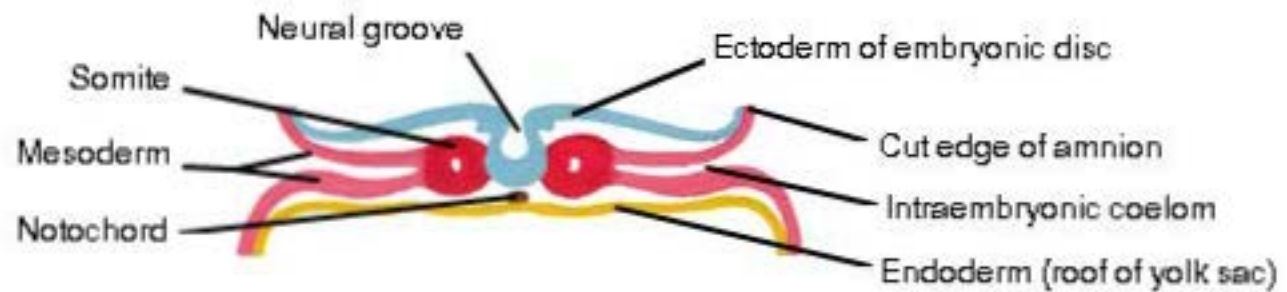


# Muscular System: Primordia

## Differentiation of somites into myotomes, sclerotomes, and dermatomes

### Cross section of human embryos

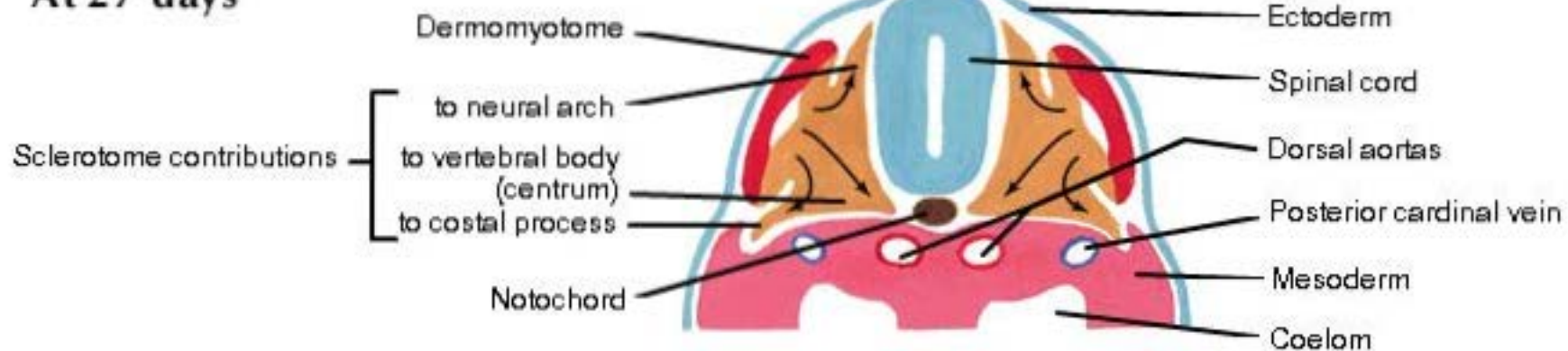
At 19 days



At 22 days



At 27 days



At 30 days

Note: Sections A, B, and C are at level of future vertebral body, but section D is at level between developing bodies

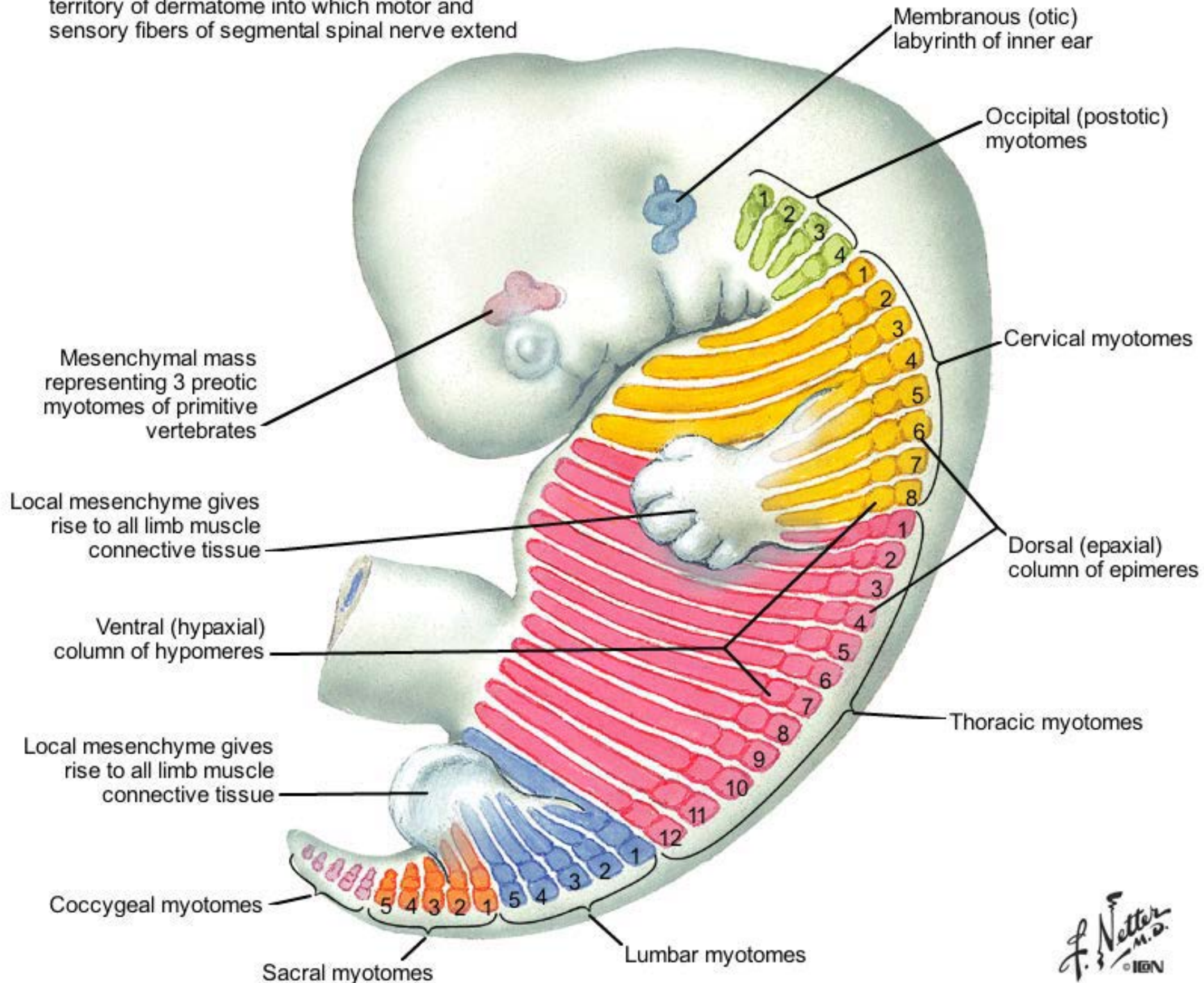




# Segmentation and Division of Myotomes

## Segmental distribution of myotomes in fetus of 6 weeks

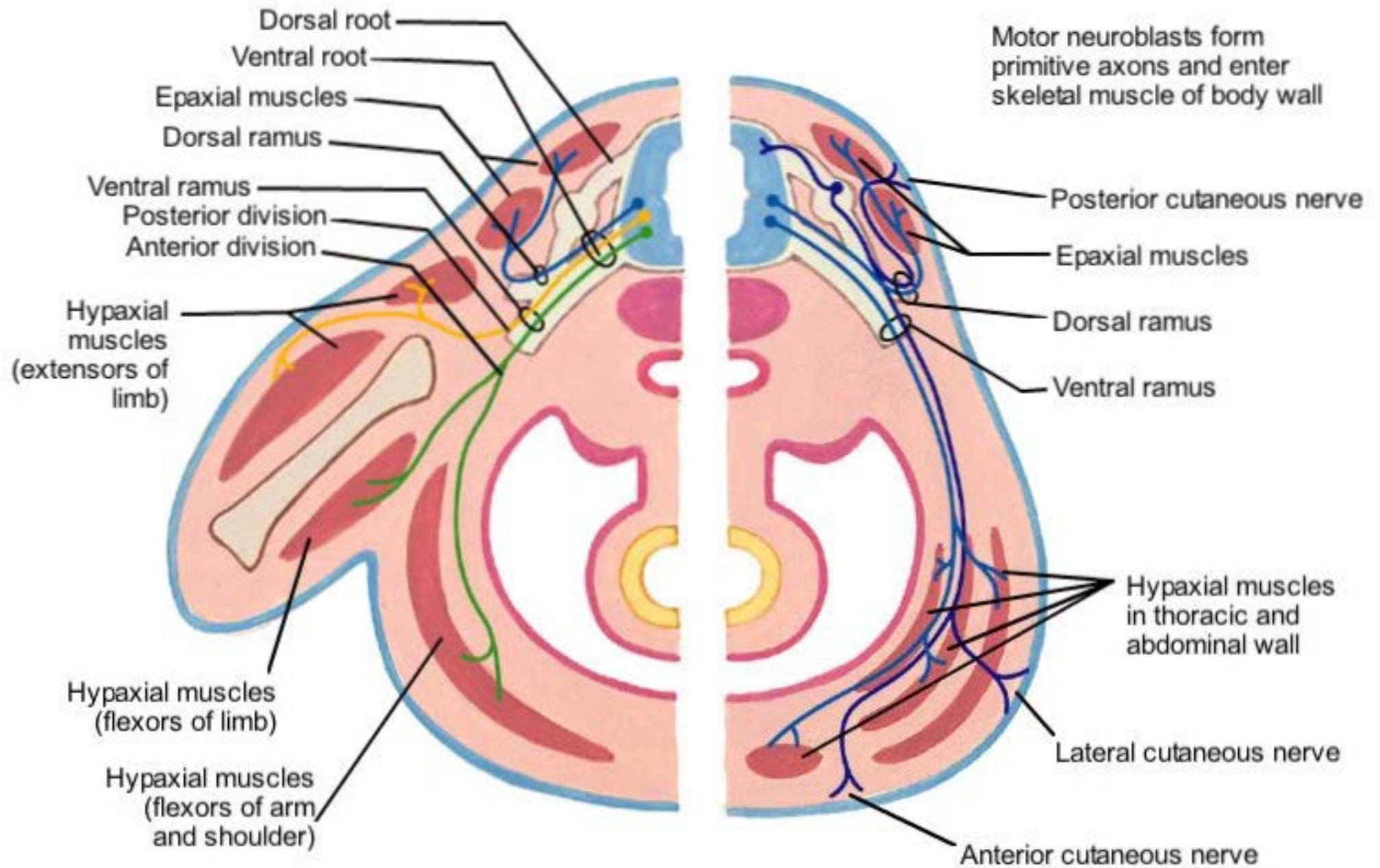
Region of each trunk myotome also represents territory of dermatome into which motor and sensory fibers of segmental spinal nerve extend





# Epimere, Hypomere, and Muscle Groups

## Somatic development

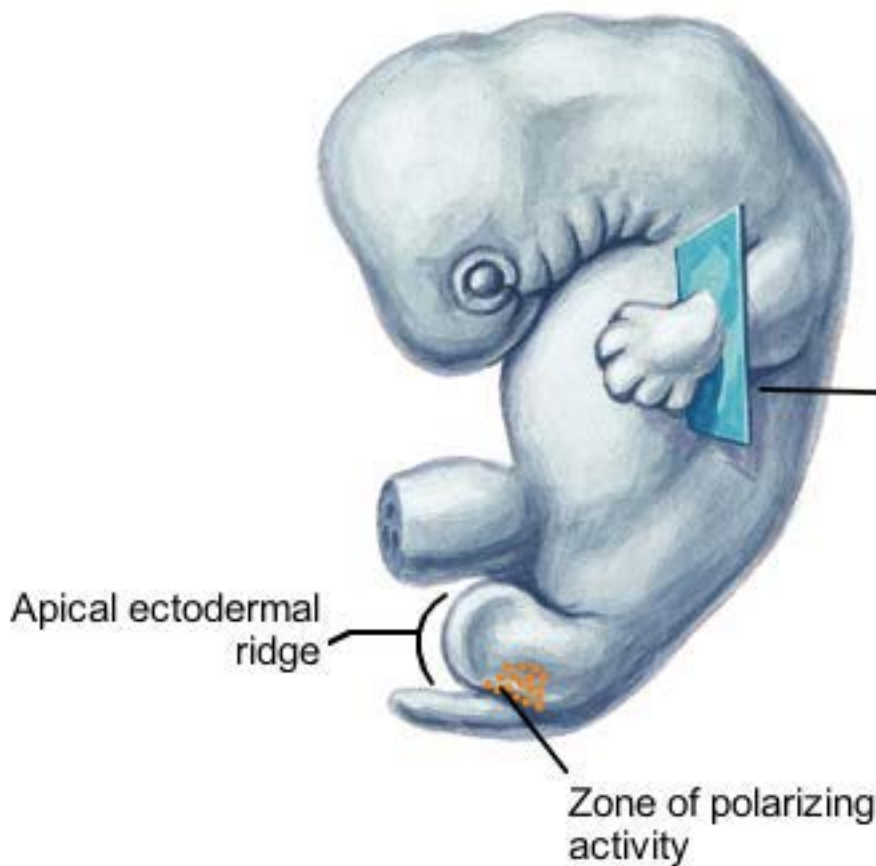


Somatic nervous system innervates somatopleure (body wall)



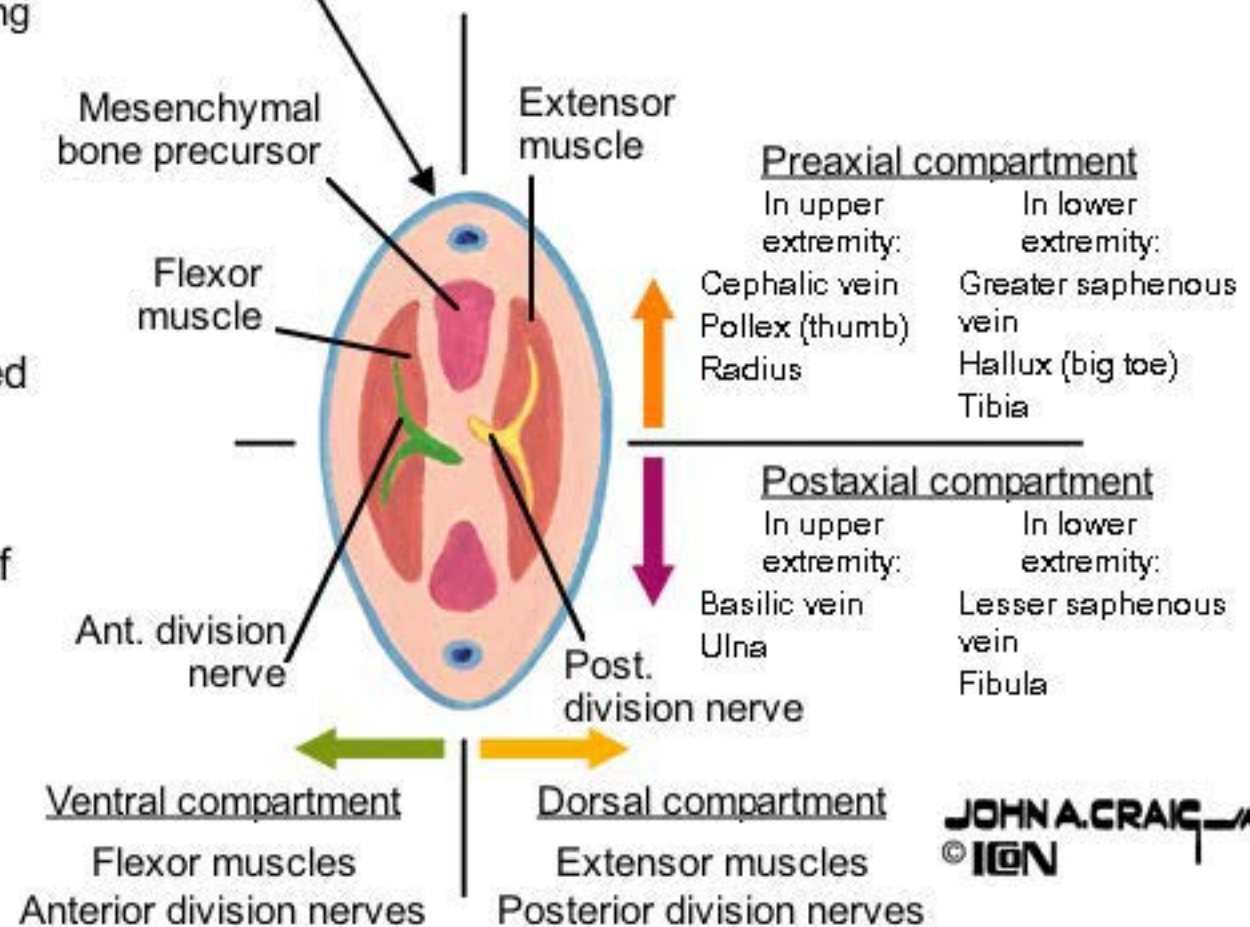
# Development and Organization of Limb Buds

## Limb buds in 6-week embryo



In the classic model of proximodistal morphological determination, the apical ectodermal ridge interacts with the underlying mesoderm of the progress zone to establish a time sequence of differentiation as the limb elongates. More recent evidence indicates that the morphological information may be programmed early on in the mesenchyme with no particular role for the ectoderm.

Early craniocaudal morphological differentiation is determined by a gradient of sonic hedgehog produced by the zone of polarizing activity (ZPA), a signaling center at the caudal end of each limb bud. The ZPA also stimulates the formation of the apical ectodermal ridge.





# Rotation of the Limbs

## Changes in position of limbs before birth



At 5 weeks. Upper and lower limbs have formed as finlike appendages pointing laterally and caudally



At 6 weeks. Limbs bend anteriorly, so elbows and knees point laterally, palms and soles face trunk



At 7 weeks. Upper and lower limbs have undergone 90-degree torsion about their long axes, but in opposite directions, so elbows point caudally and knees cranially



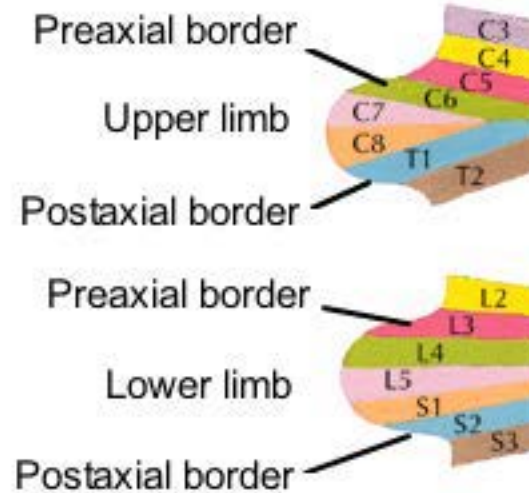
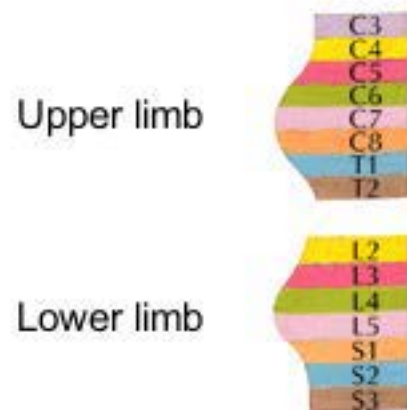
At 8 weeks. Torsion of lower limbs results in twisted or "barber pole" arrangement of their cutaneous innervation



# Limb Rotation and Dermatomes

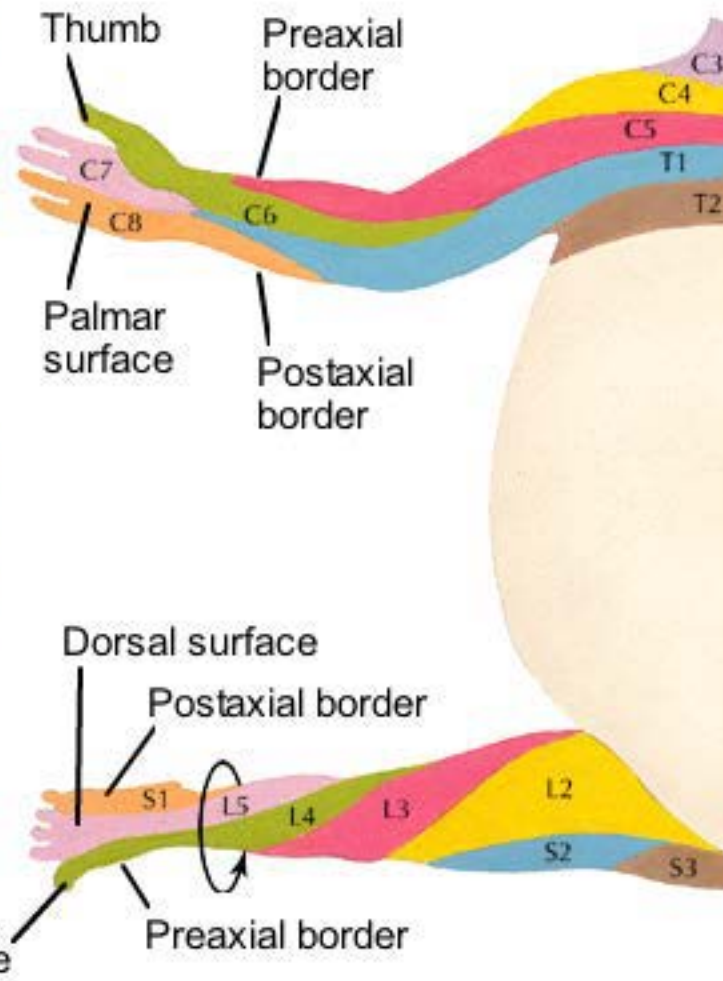
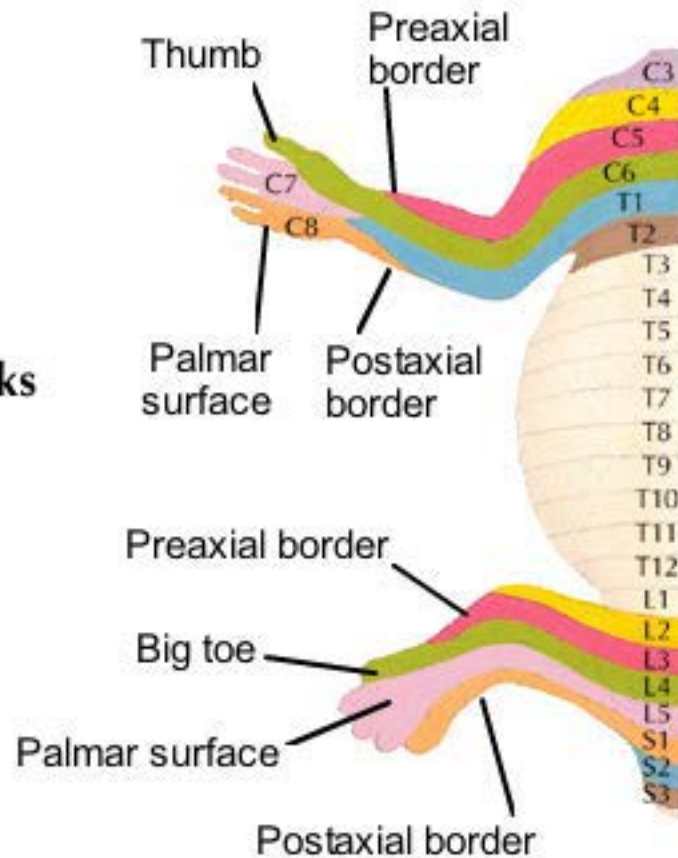
Changes in ventral dermatome pattern (cutaneous sensory nerve distribution) during limb development

At 4 weeks



At 5 weeks

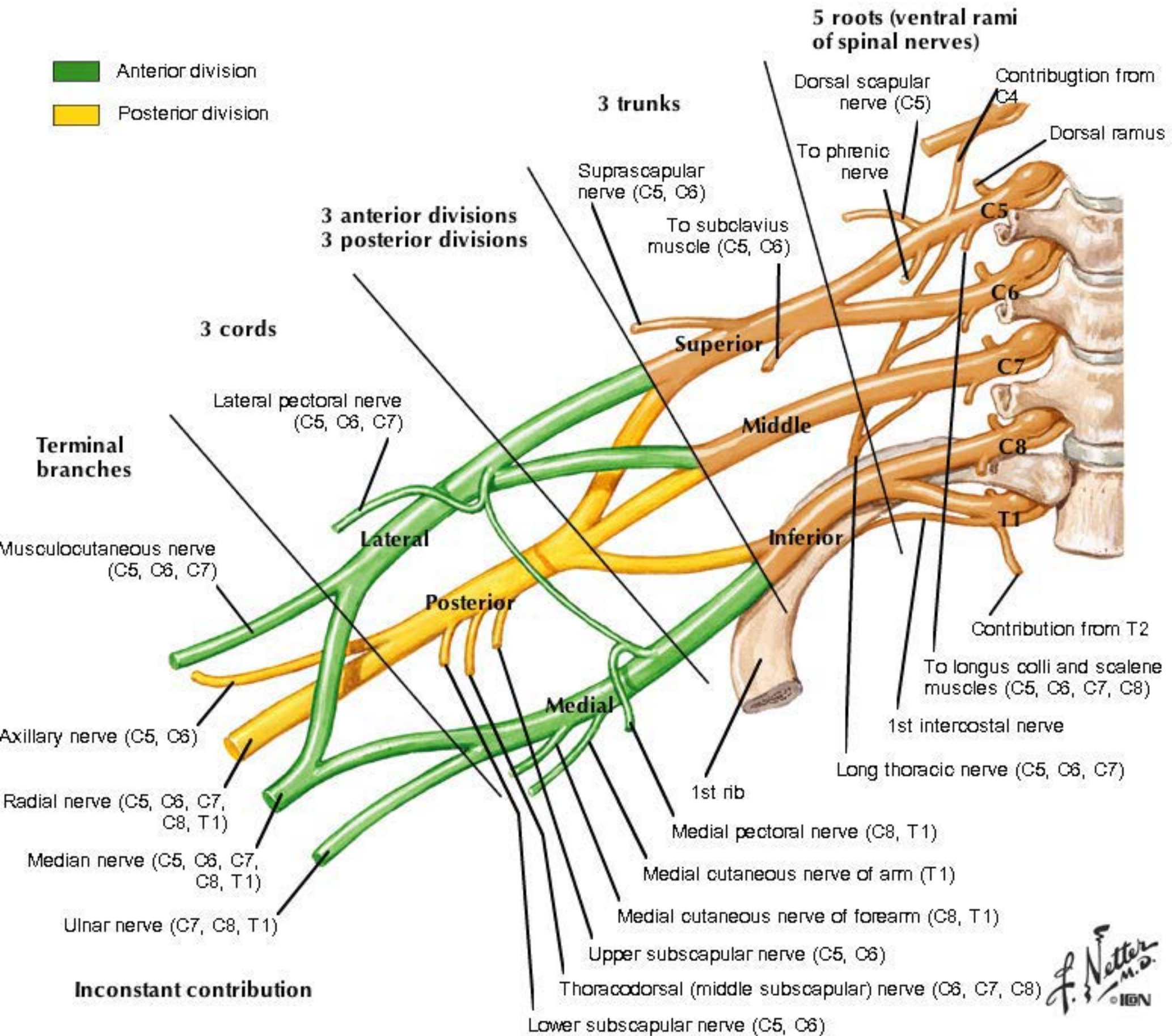
At 7 weeks



At 8 weeks

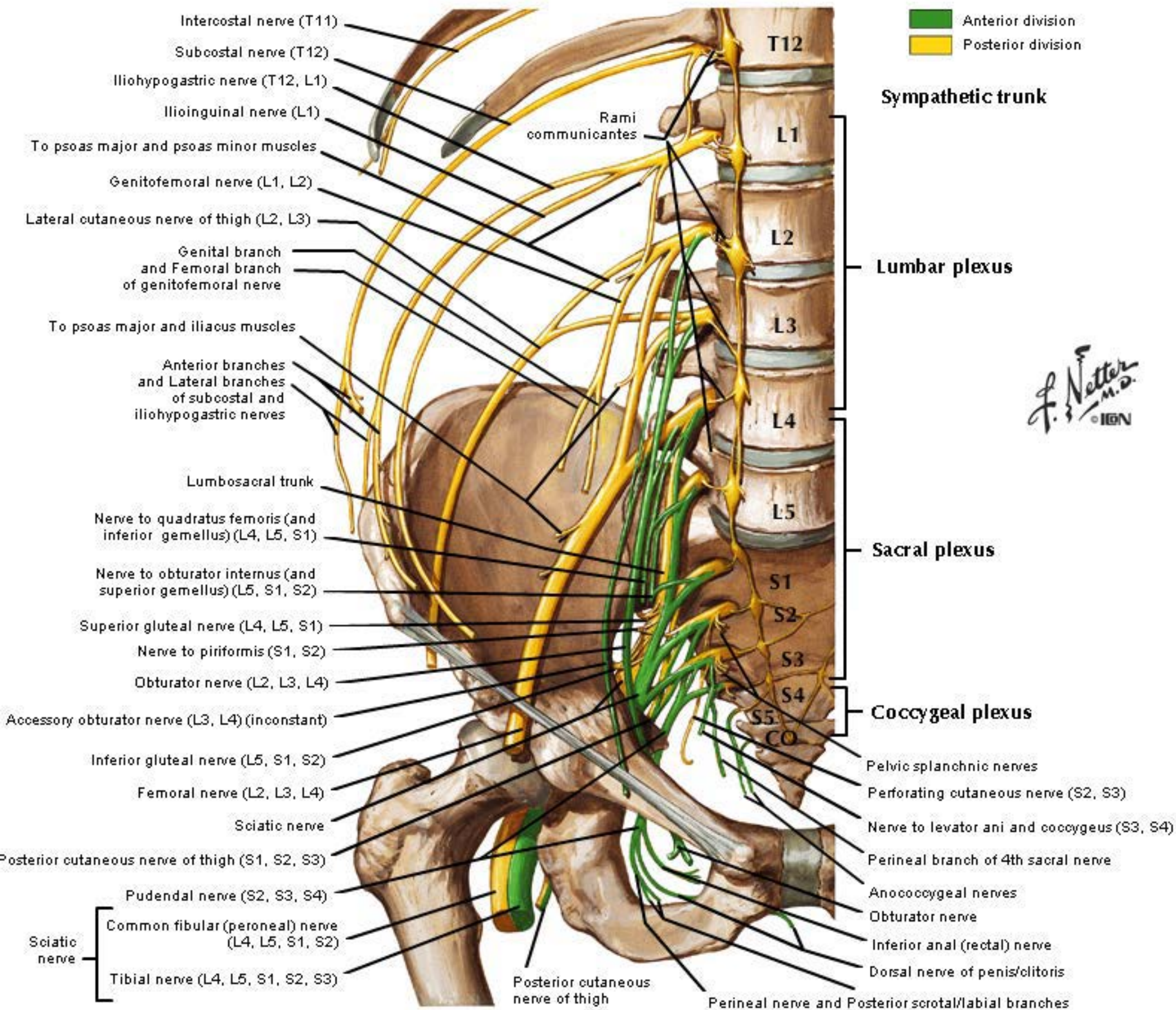
# Embryonic Plan of the Brachial Plexus

## Comparison of embryonic limb organization to the plan of the brachial plexus





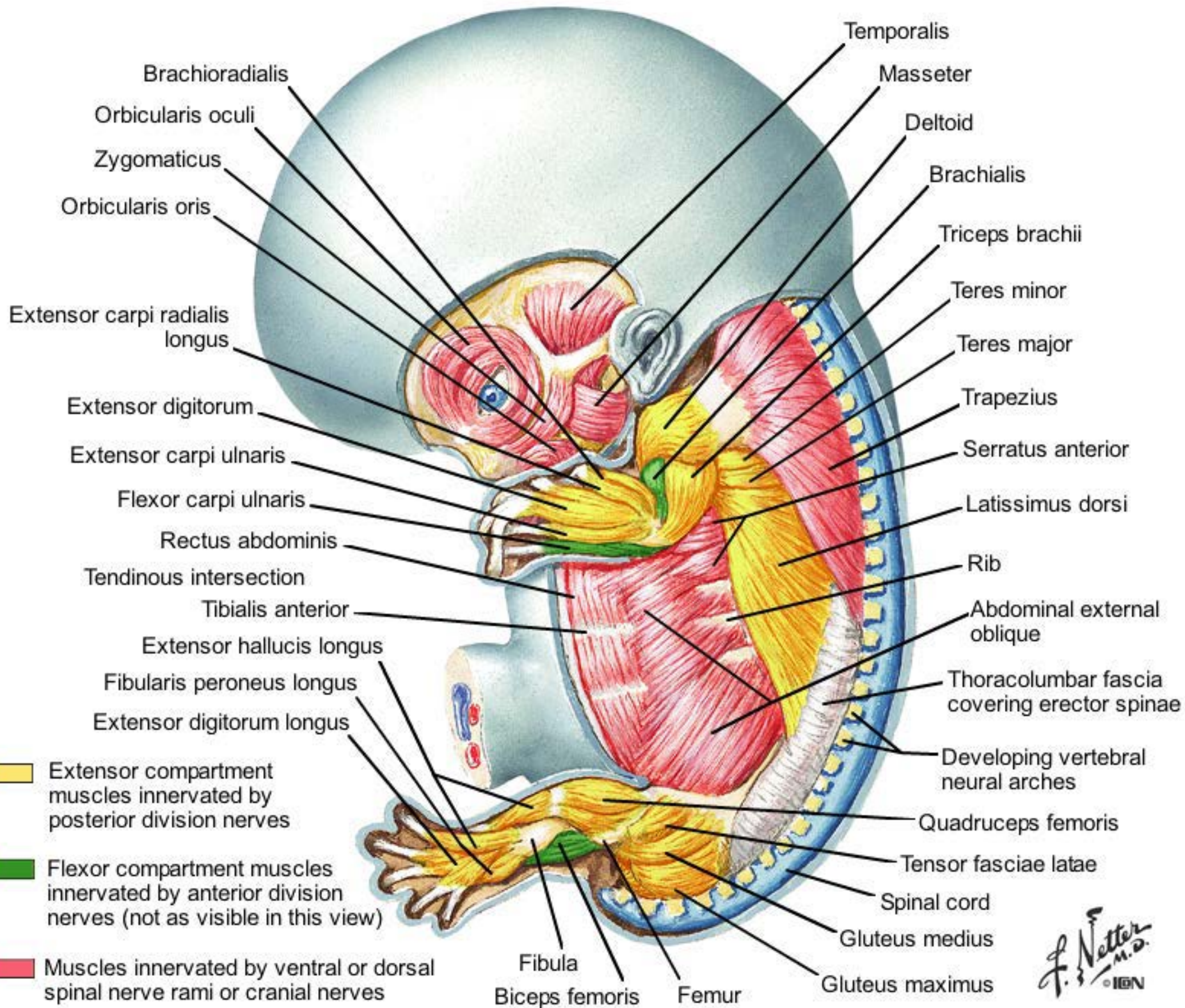
# Divisions of the Lumbosacral Plexus





# Developing Skeletal Muscles

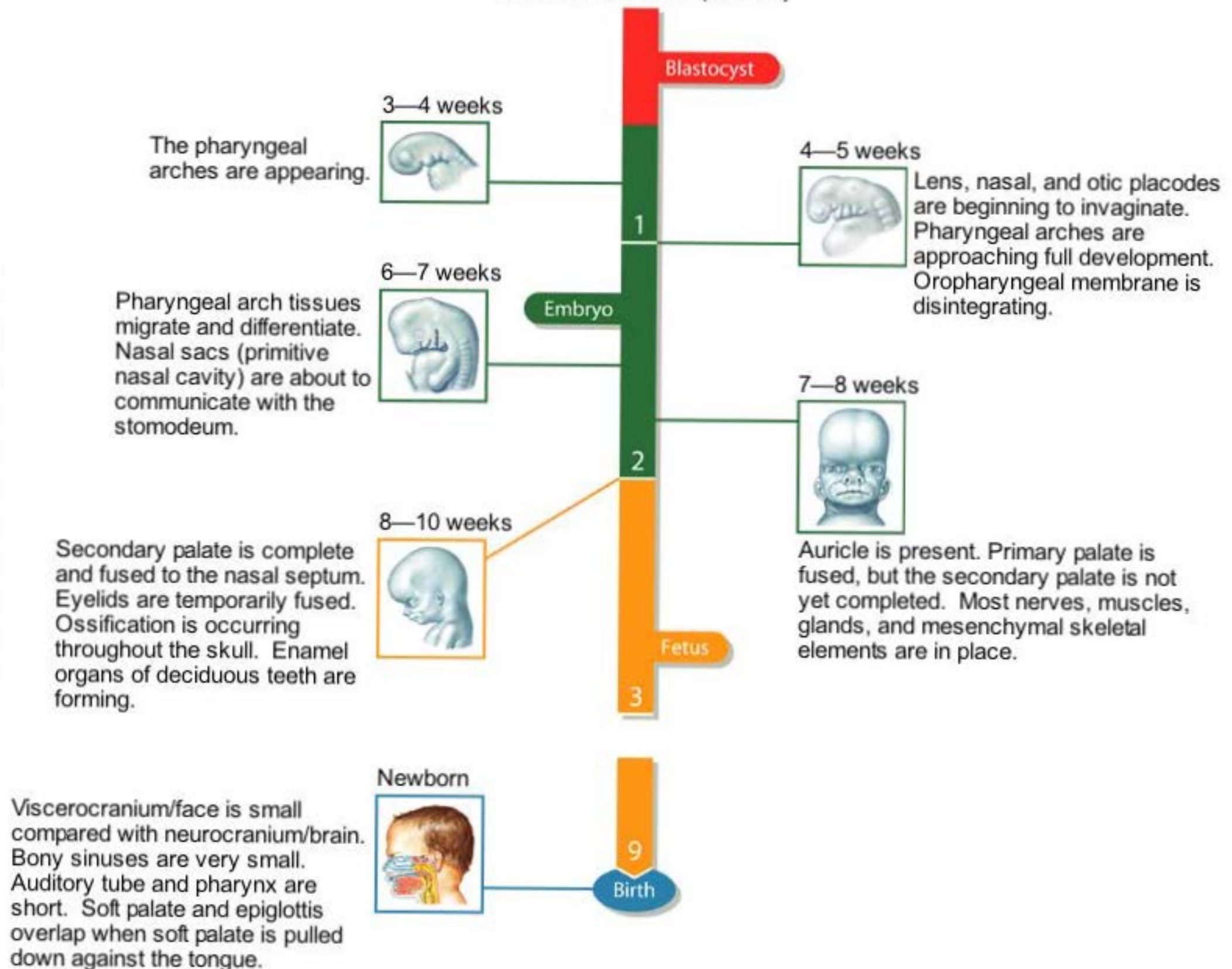
## Developing skeletal muscles at 8 weeks (superficial exposure)





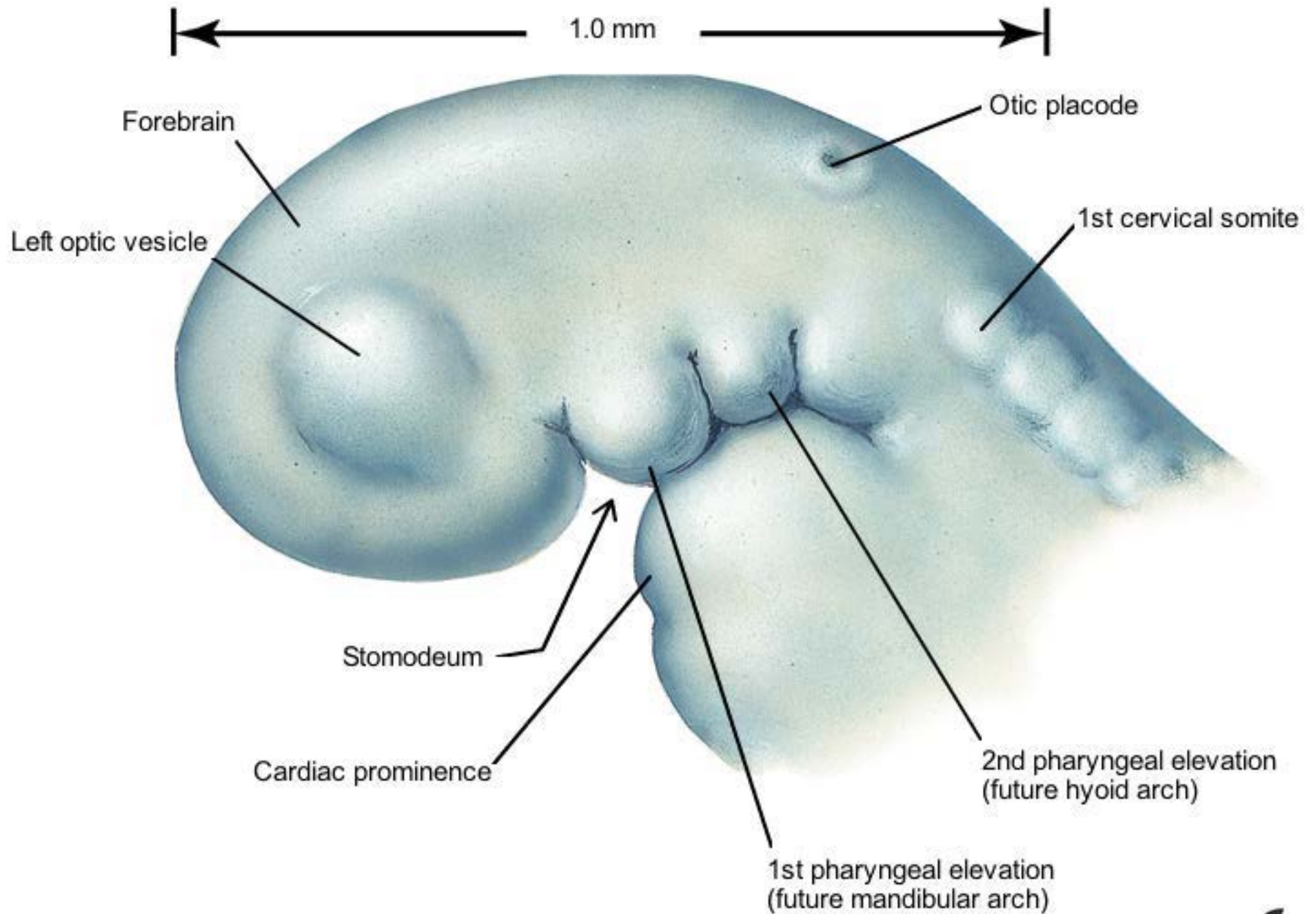
# HEAD AND NECK TIMELINE

Prenatal Time Scale (Months)



# Ectoderm, Endoderm, and Mesoderm

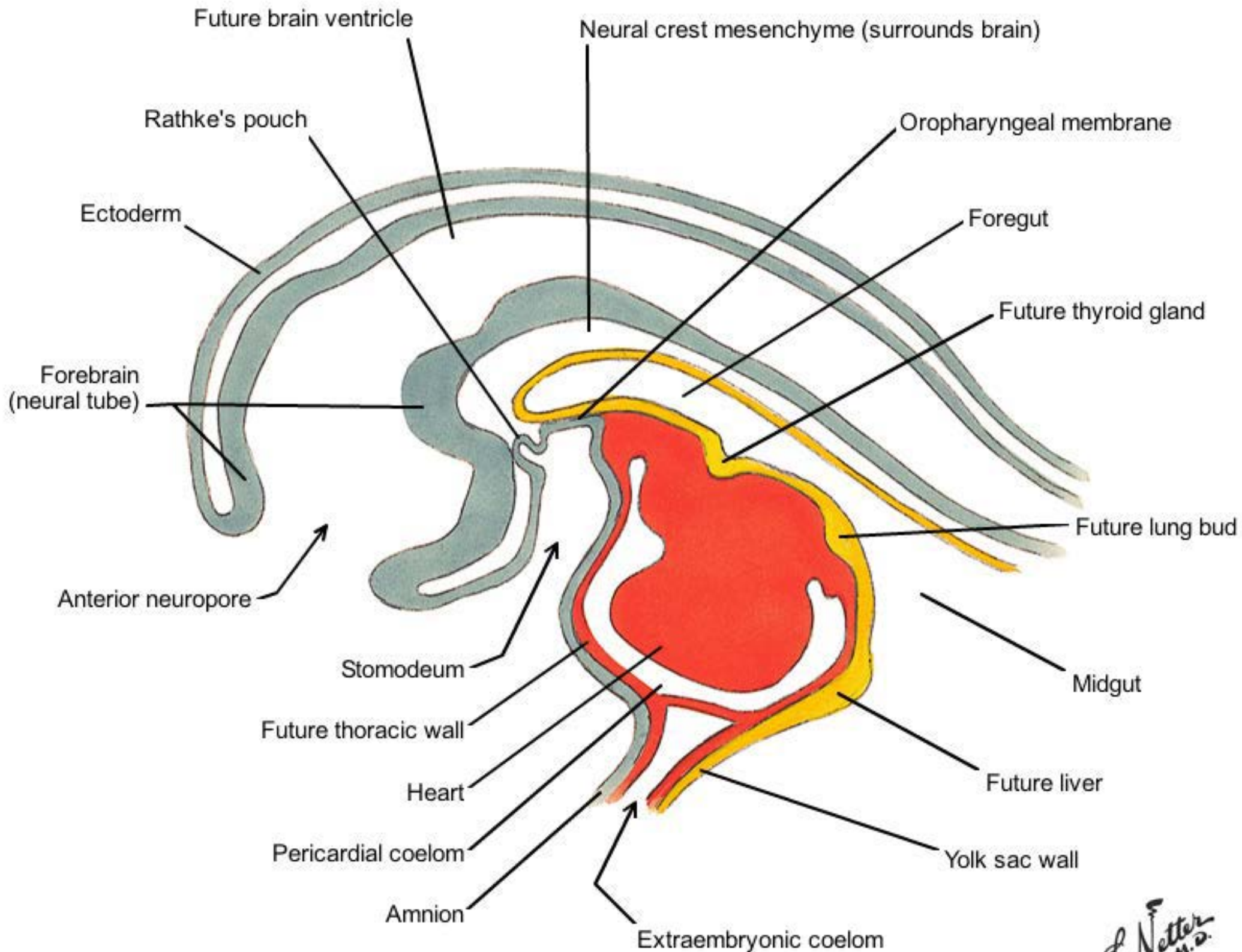
## Lateral view (3 to 4 weeks)





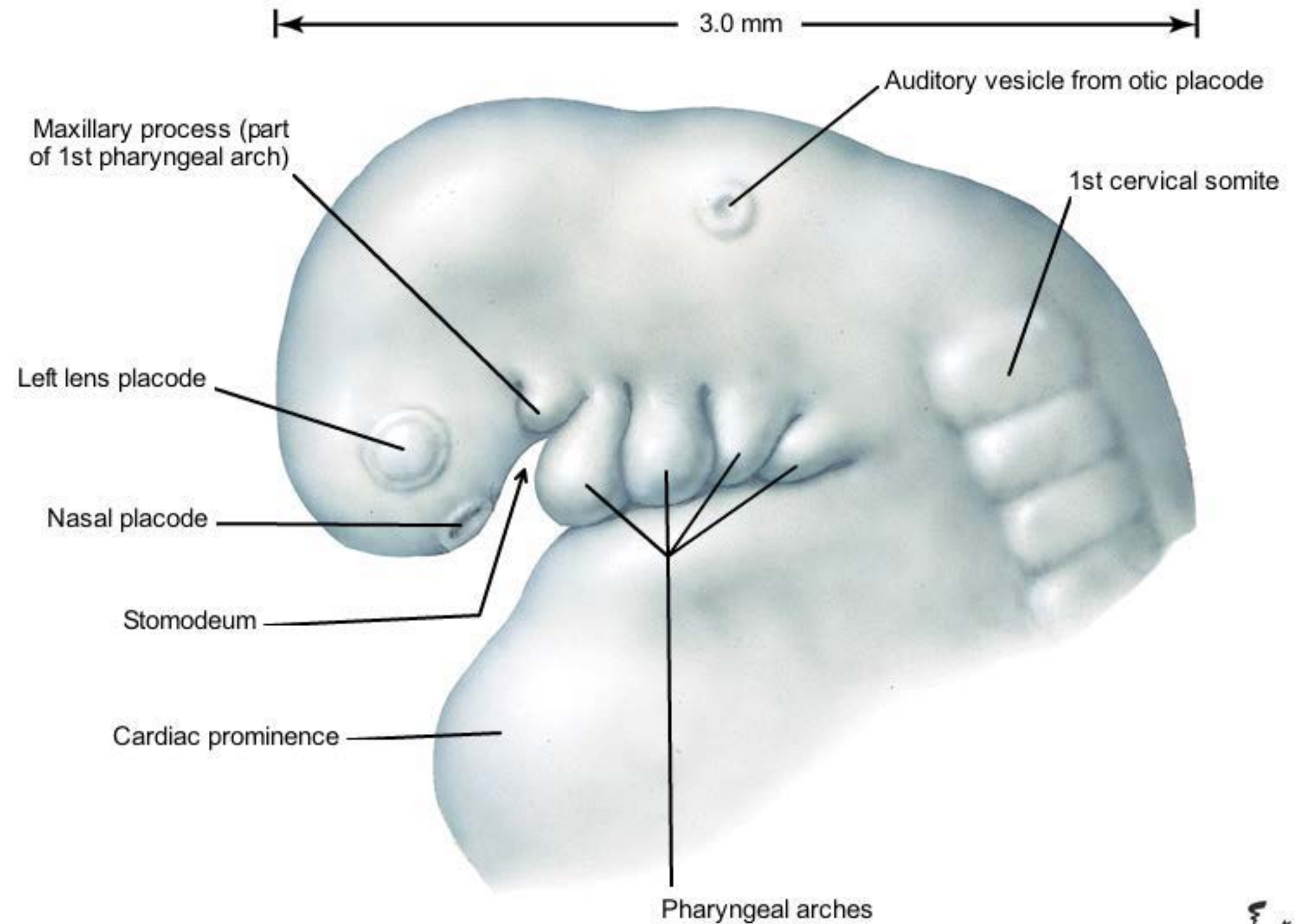
# Ectoderm, Endoderm, and Mesoderm

Sagittal section (3 to 4 weeks)



# Ectoderm, Endoderm, and Mesoderm

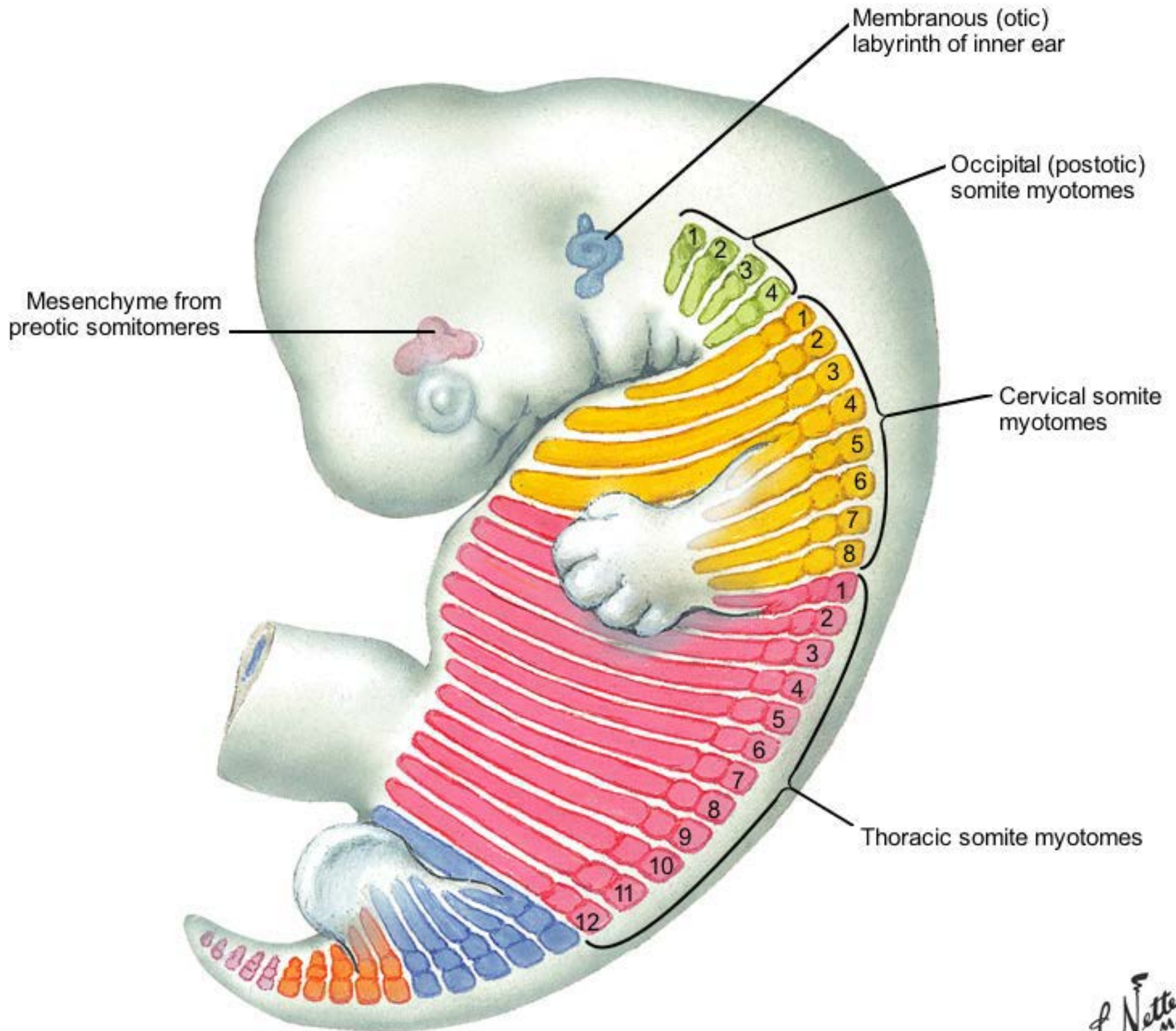
Lateral view (4 to 5 weeks)





# Ectoderm, Endoderm, and Mesoderm

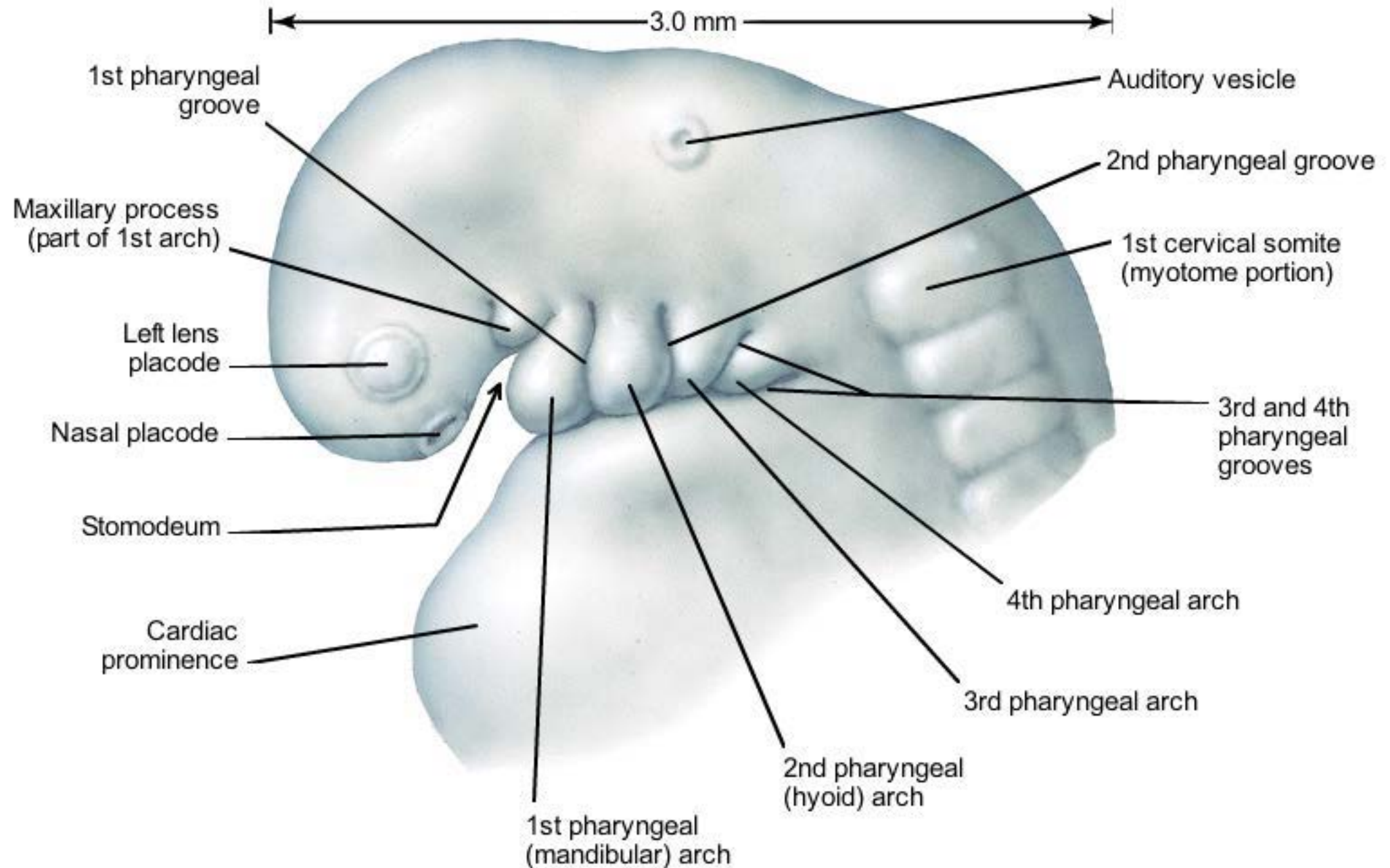
Somites and somitomeres (6 weeks)



# Pharyngeal (Branchial) Arches

Embryo at 4 to 5 weeks

Lateral View

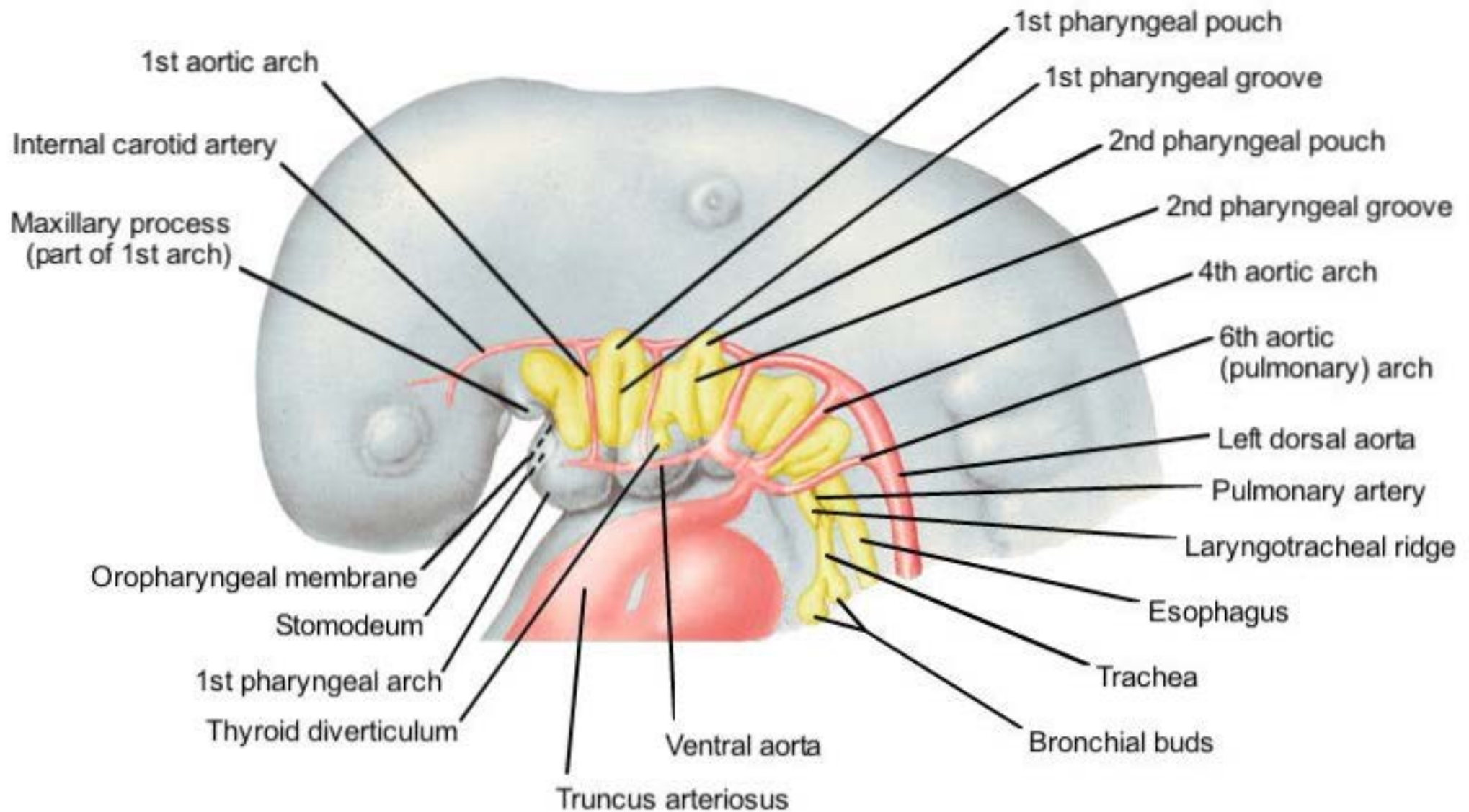




# Pharyngeal (Branchial) Arches

## Pharyngeal pouches and aortic arch arteries

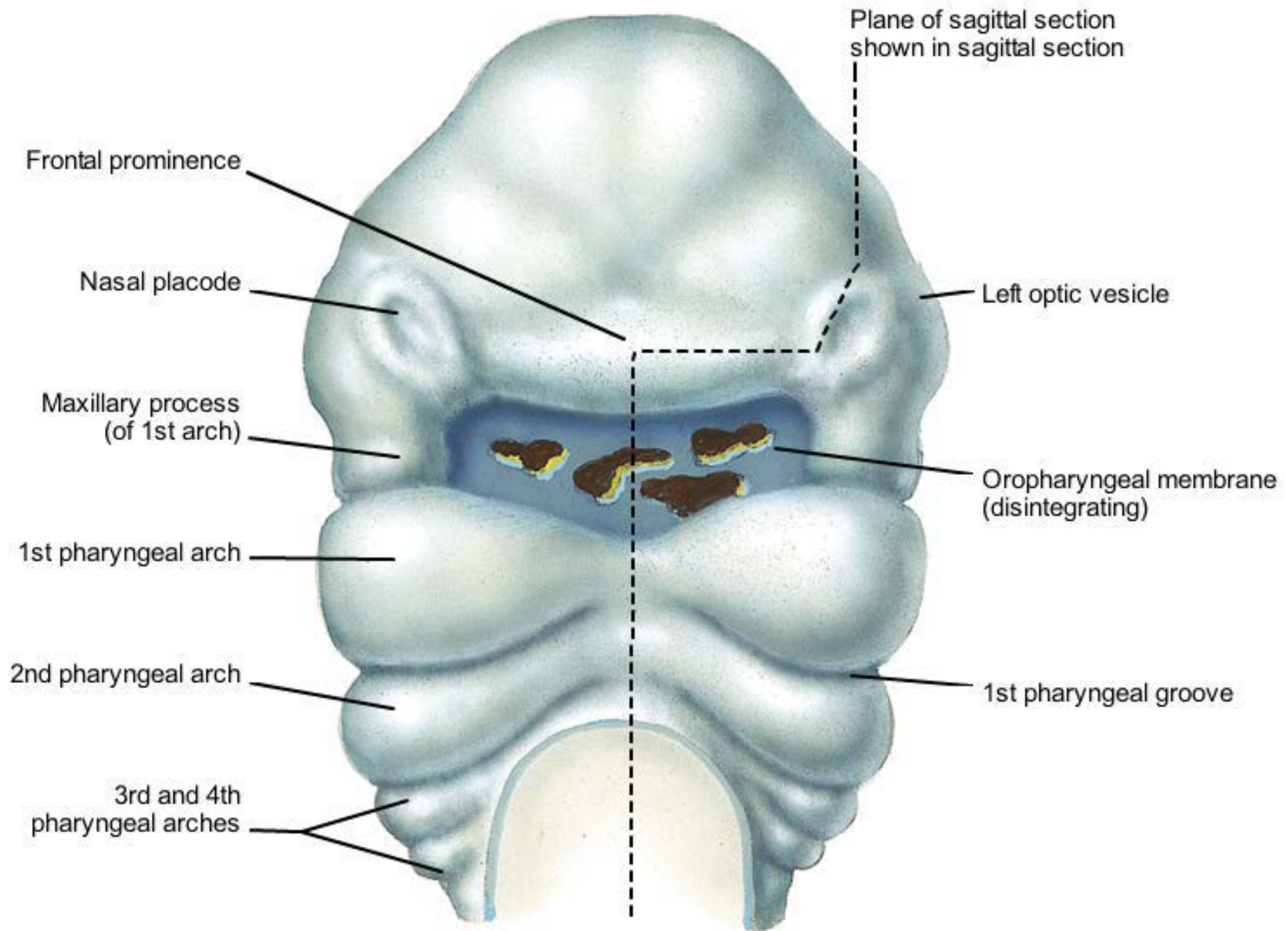
### Lateral View



# Ventral and Midsagittal Views

Embryo at 4 to 5 weeks

## Ventral view

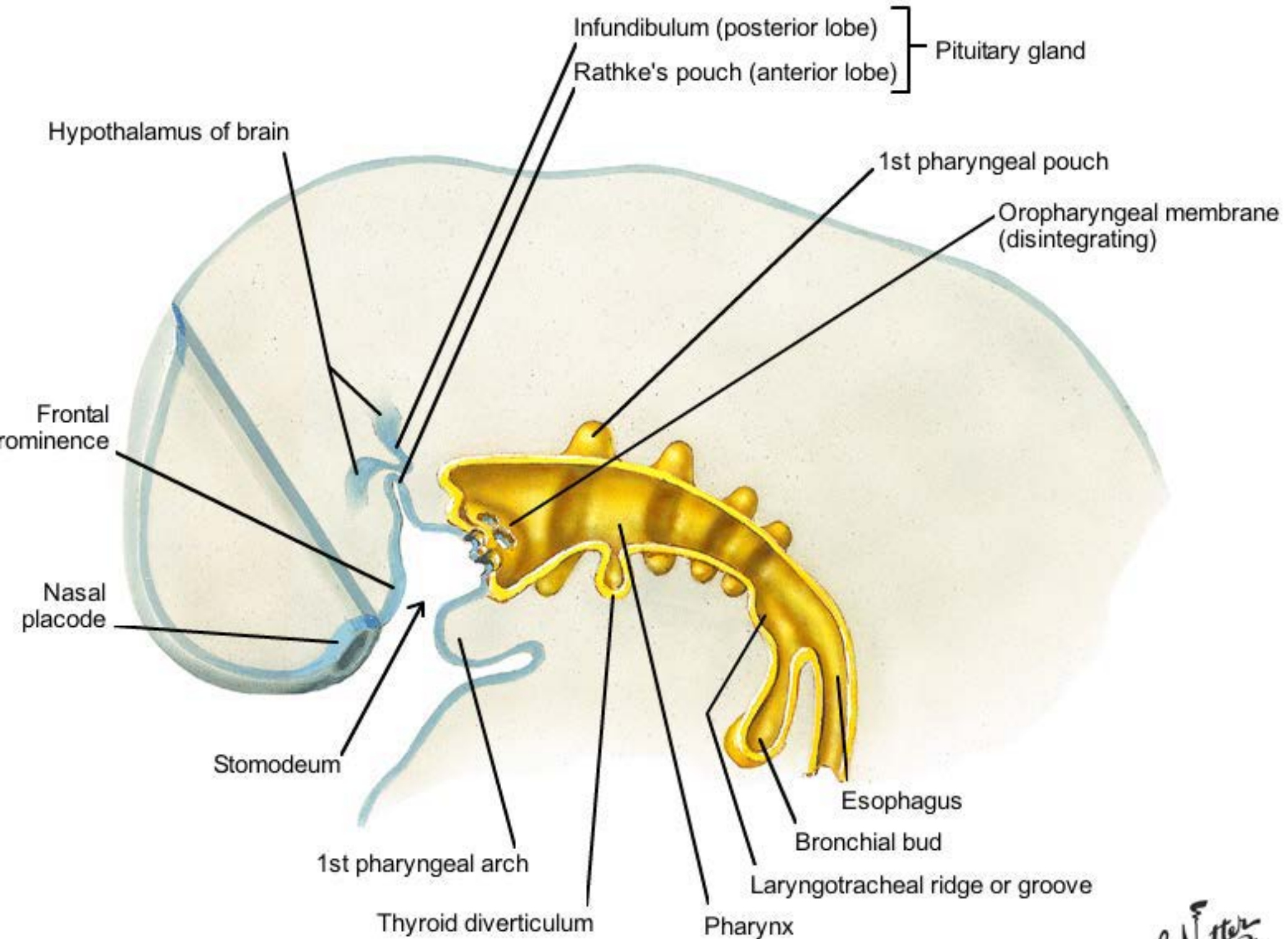




# Ventral and Midsagittal Views

Embryo at 4 to 5 weeks

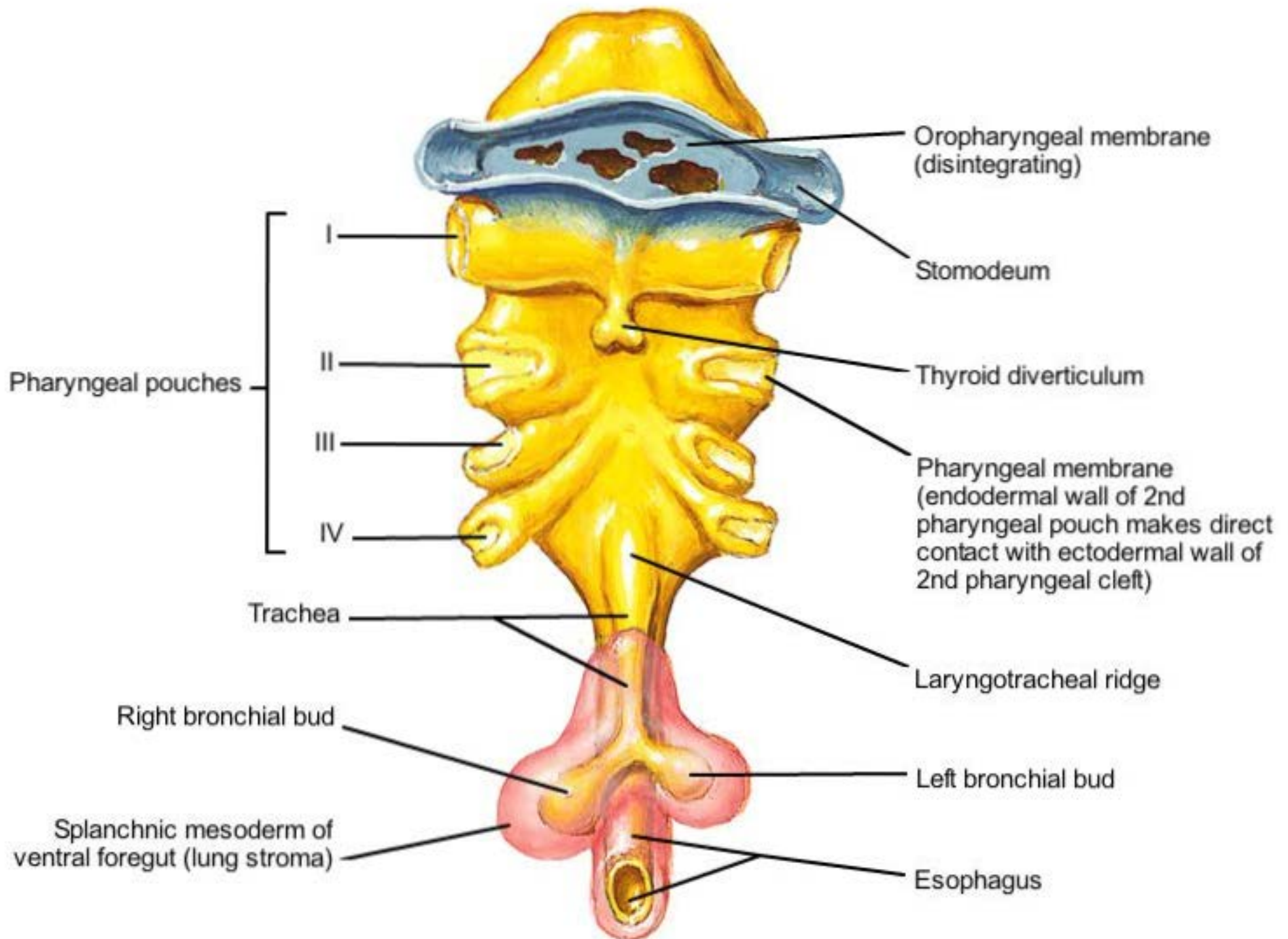
## Sagittal section



# Fate of the Pharyngeal Pouches

Embryo at 4 to 5 weeks

Pharynx (ventral view)

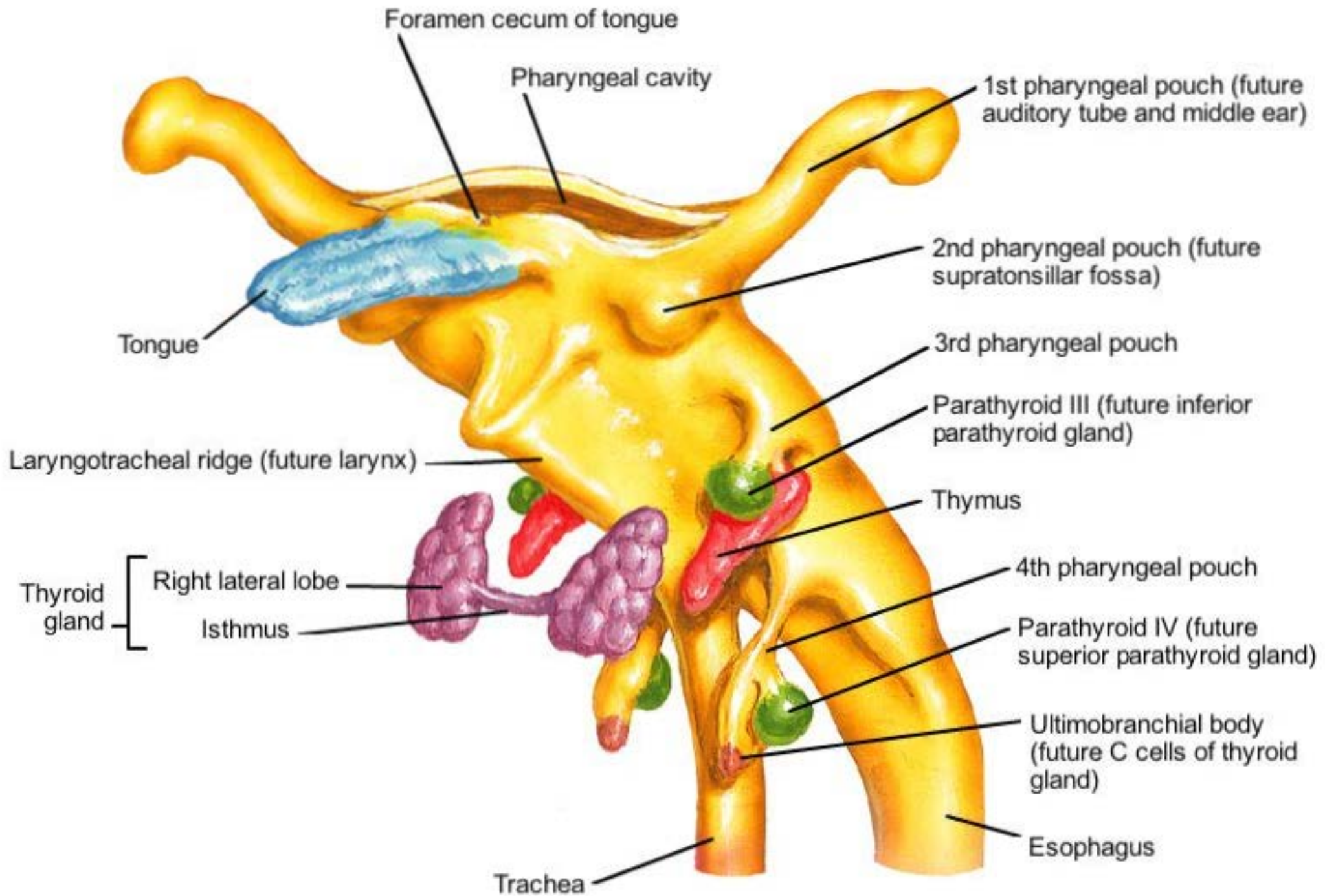




# Fate of the Pharyngeal Pouches

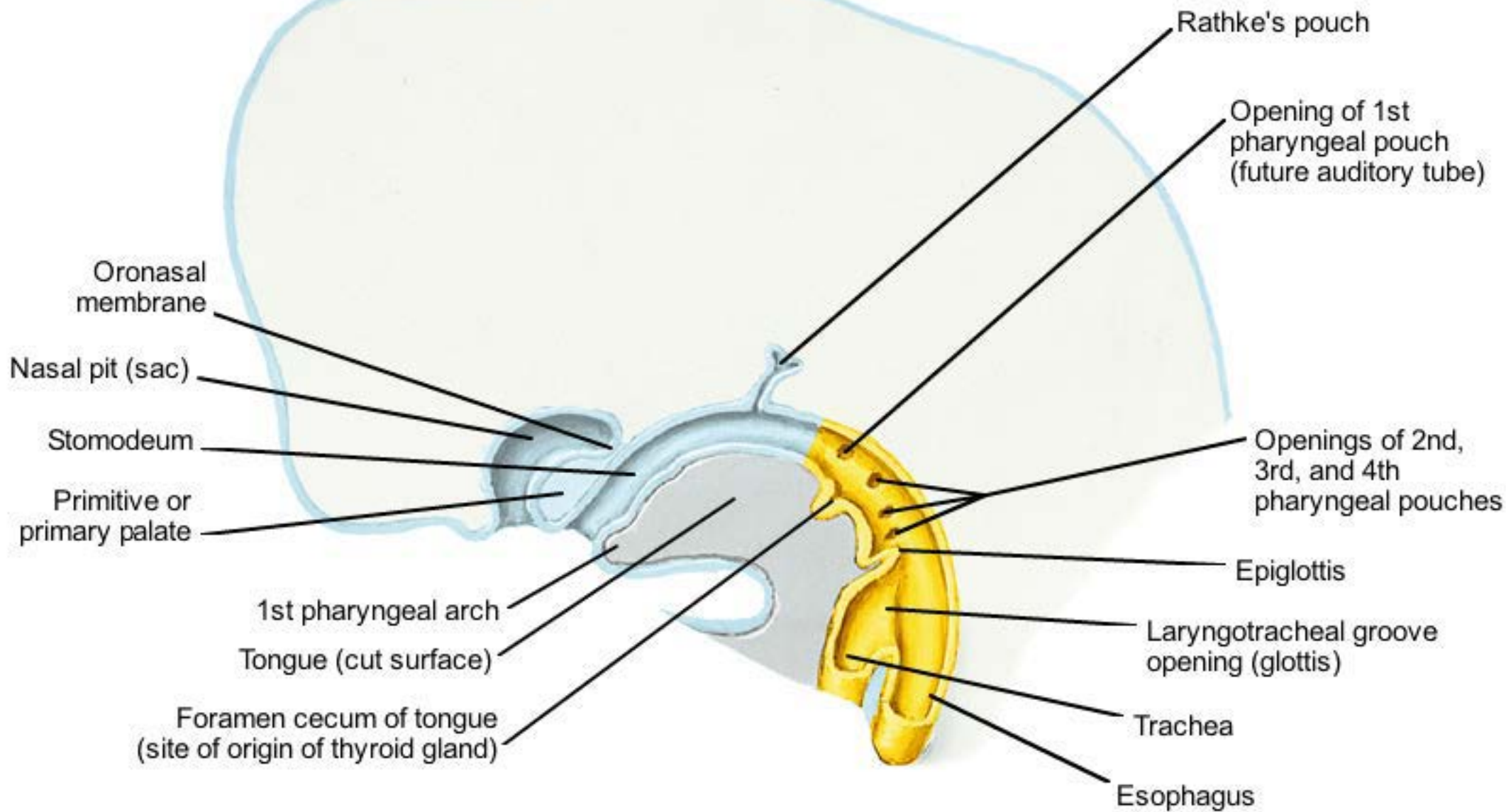
Embryo at 4 to 5 Weeks

Pharynx (anterior view of left side)



# Midsagittal View of the Pharynx

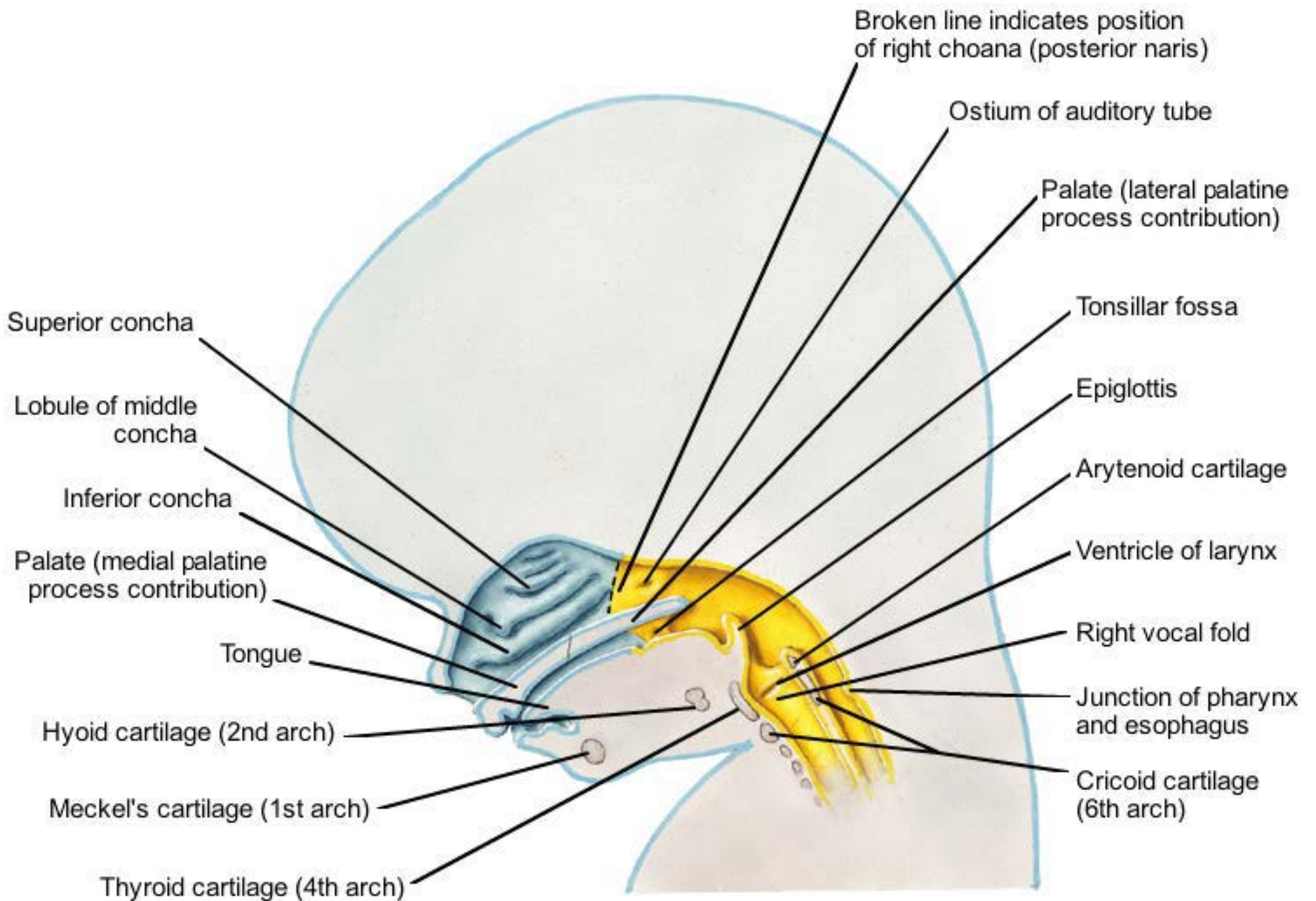
## Sagittal section at 5 to 6 weeks





# Midsagittal View of the Pharynx

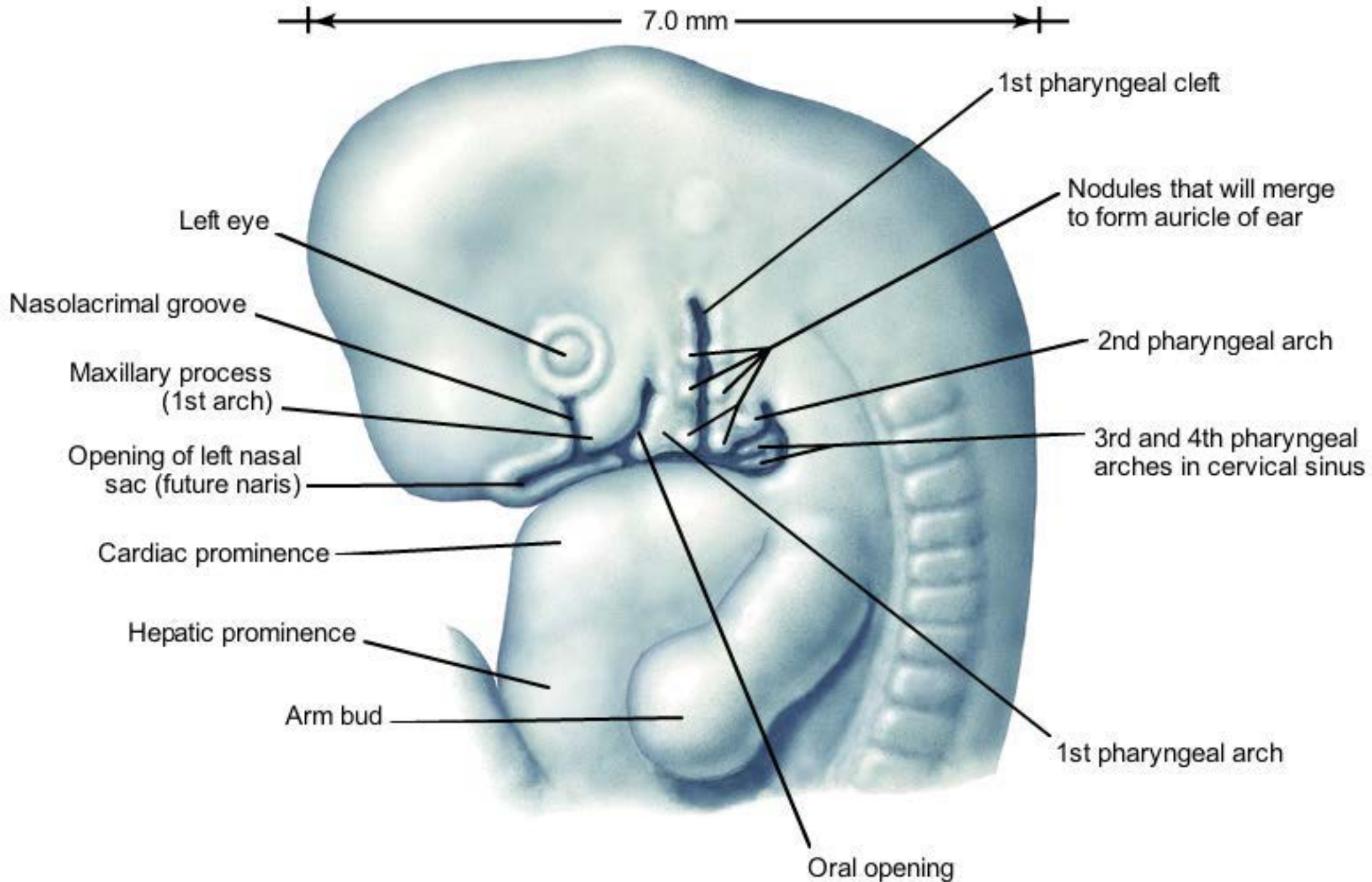
## Sagittal section at 8 to 10 weeks



# Fate of the Pharyngeal Grooves

## Lateral view at 6 to 7 weeks

Embryo at 6 to 8 weeks



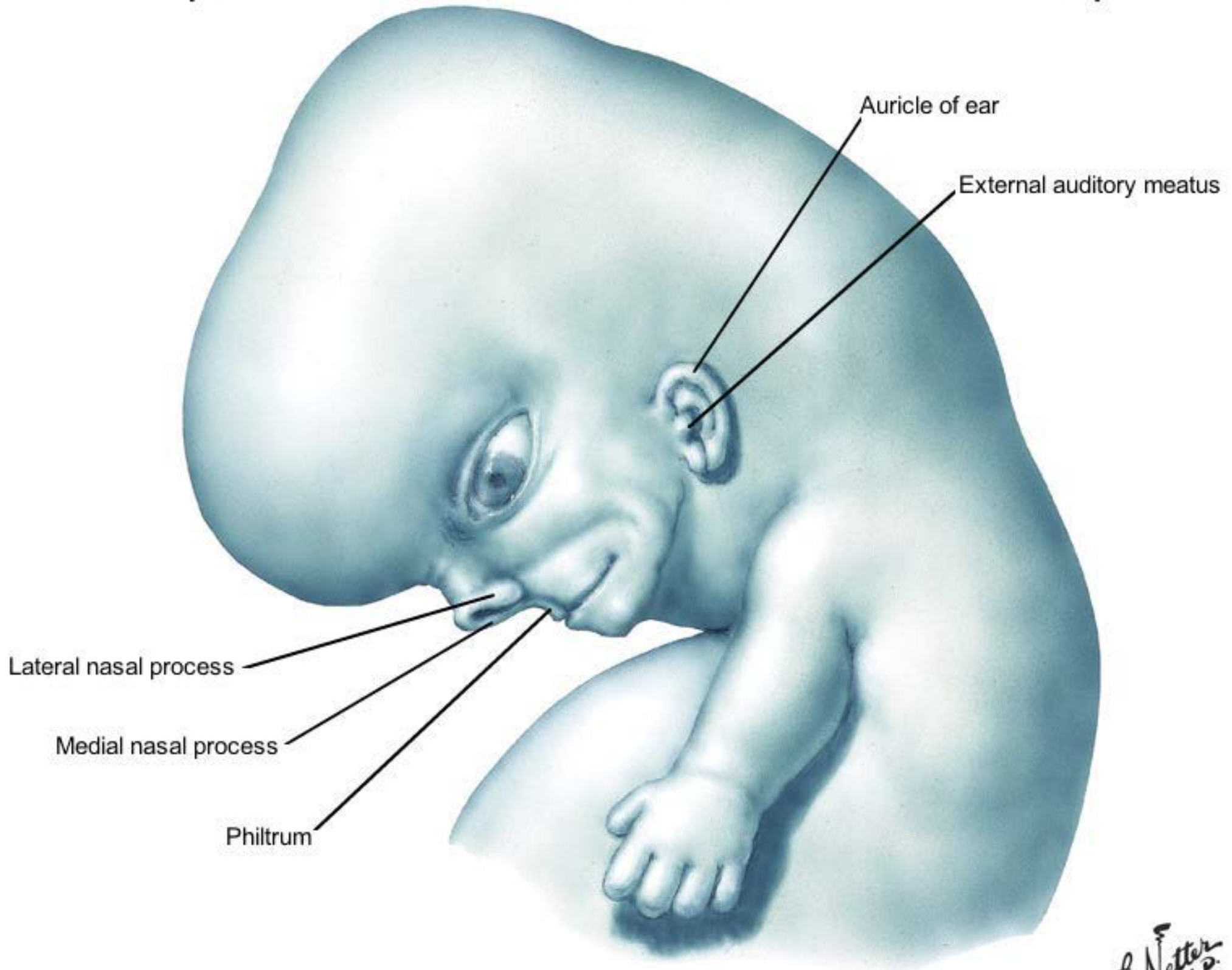


# Fate of the Pharyngeal Grooves

## Lateral view at 7 to 8 weeks

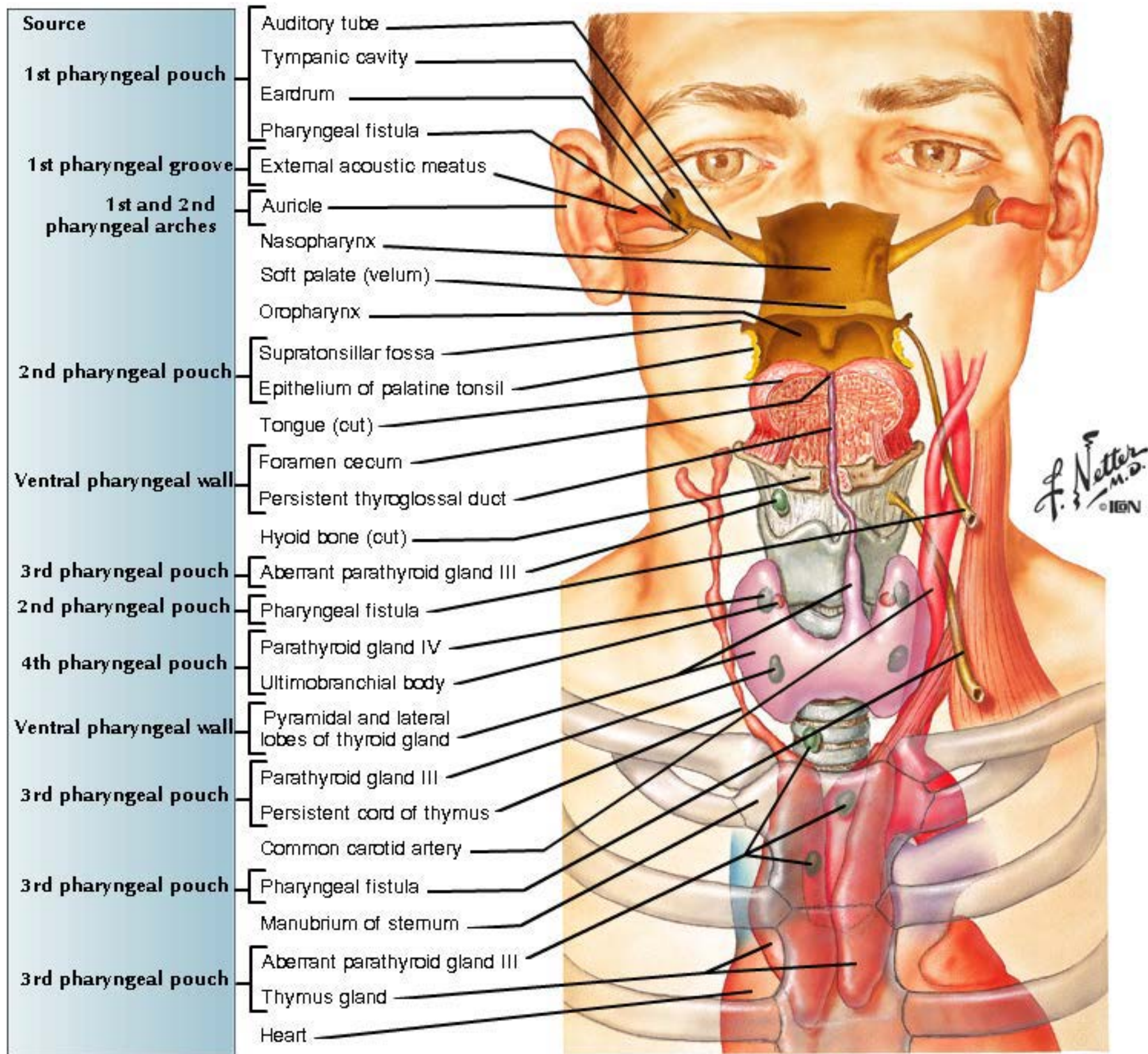
Embryo at 6 to 8 weeks

10.0 mm



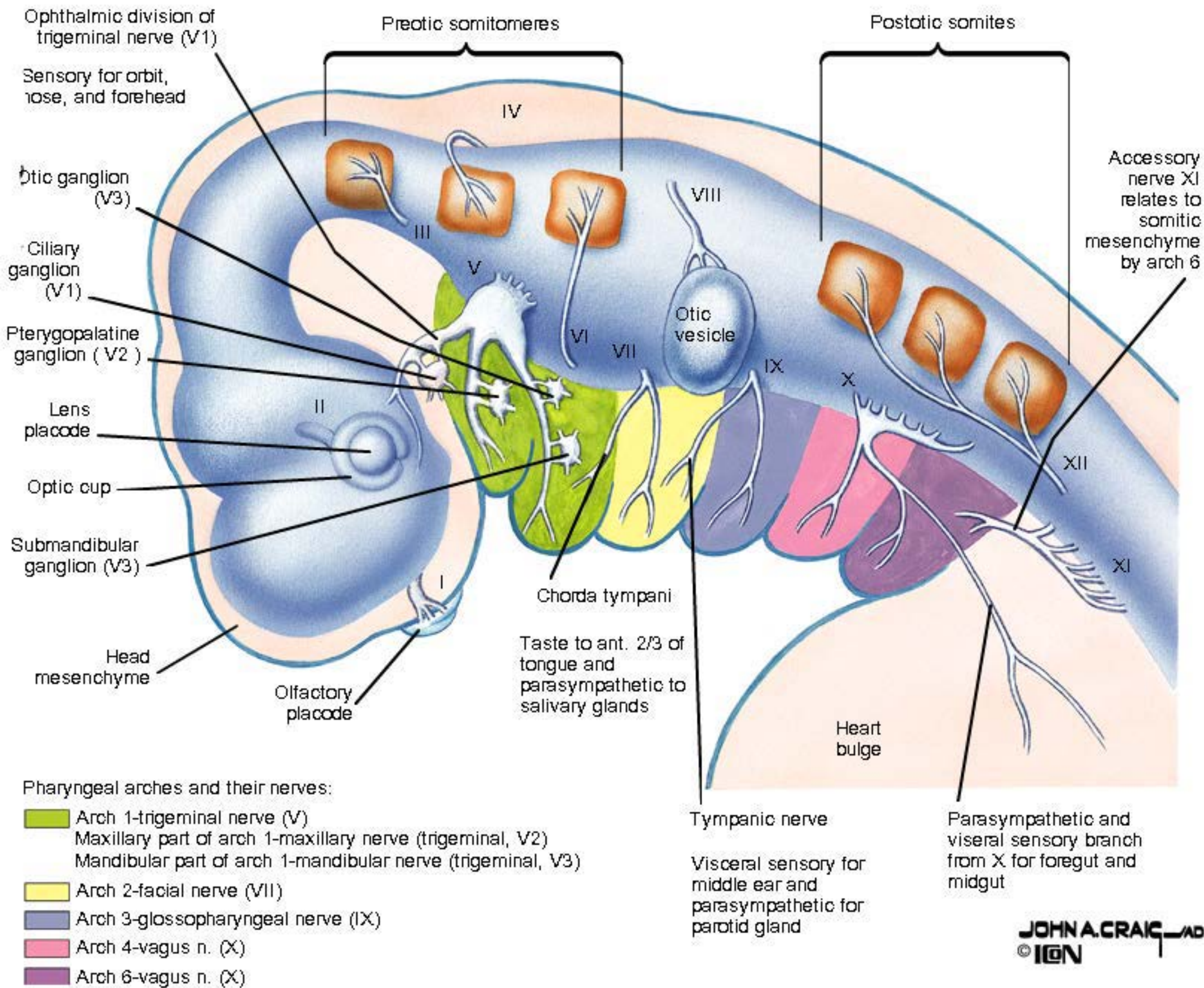


# Pharyngeal Groove and Pouch Anomalies





# Pharyngeal Arch Nerves



# Sensory Innervation Territories

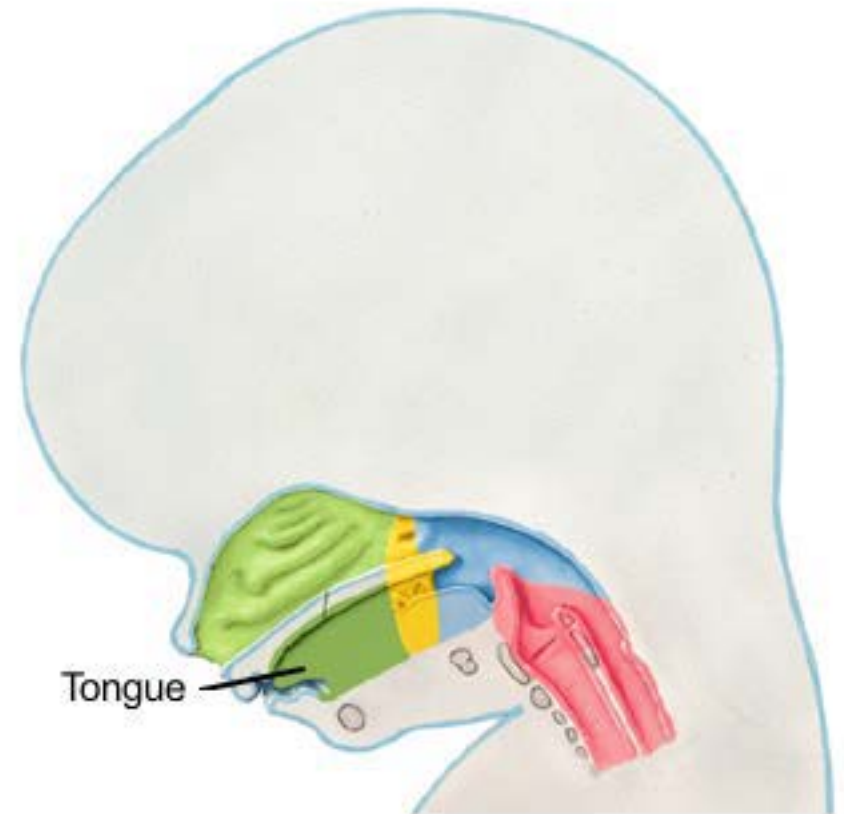
What the sensory nerve territories would be if the embryonic pattern of the pharyngeal arches were retained

Lateral view at 8 to 10 weeks






24.0 mm



Sagittal section at 8 to 10 weeks



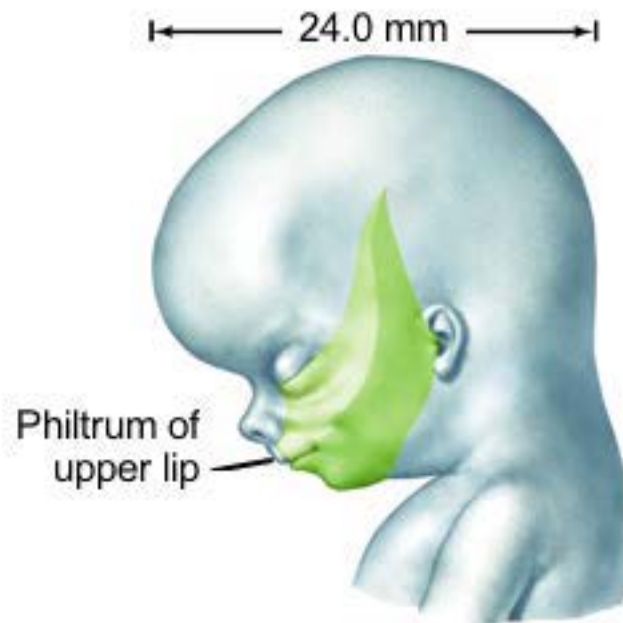
Cranial nerves:

-  Trigeminal (V1)- Arch 1 (maxillary)
-  Trigeminal (V2)-Arch 1 (mandibular)
-  Facial (VII)-Arch 2
-  Glossopharyngeal-Arch 3
-  Vagus (X)-Arches 4 and 6

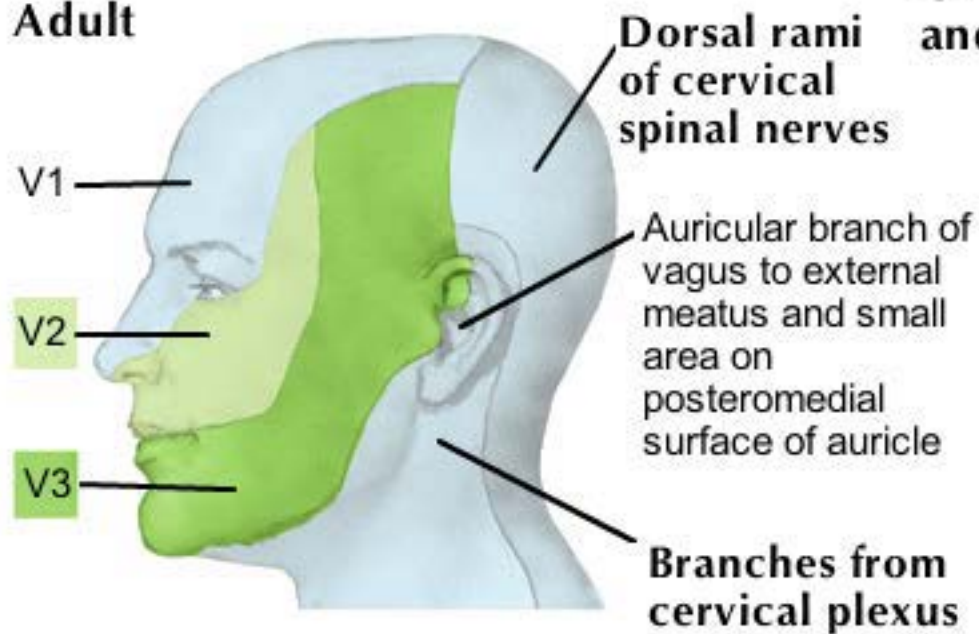


# Sensory Innervation Territories

## What the sensory territories actually are



**Adult**



**Oral cavity and pharynx**

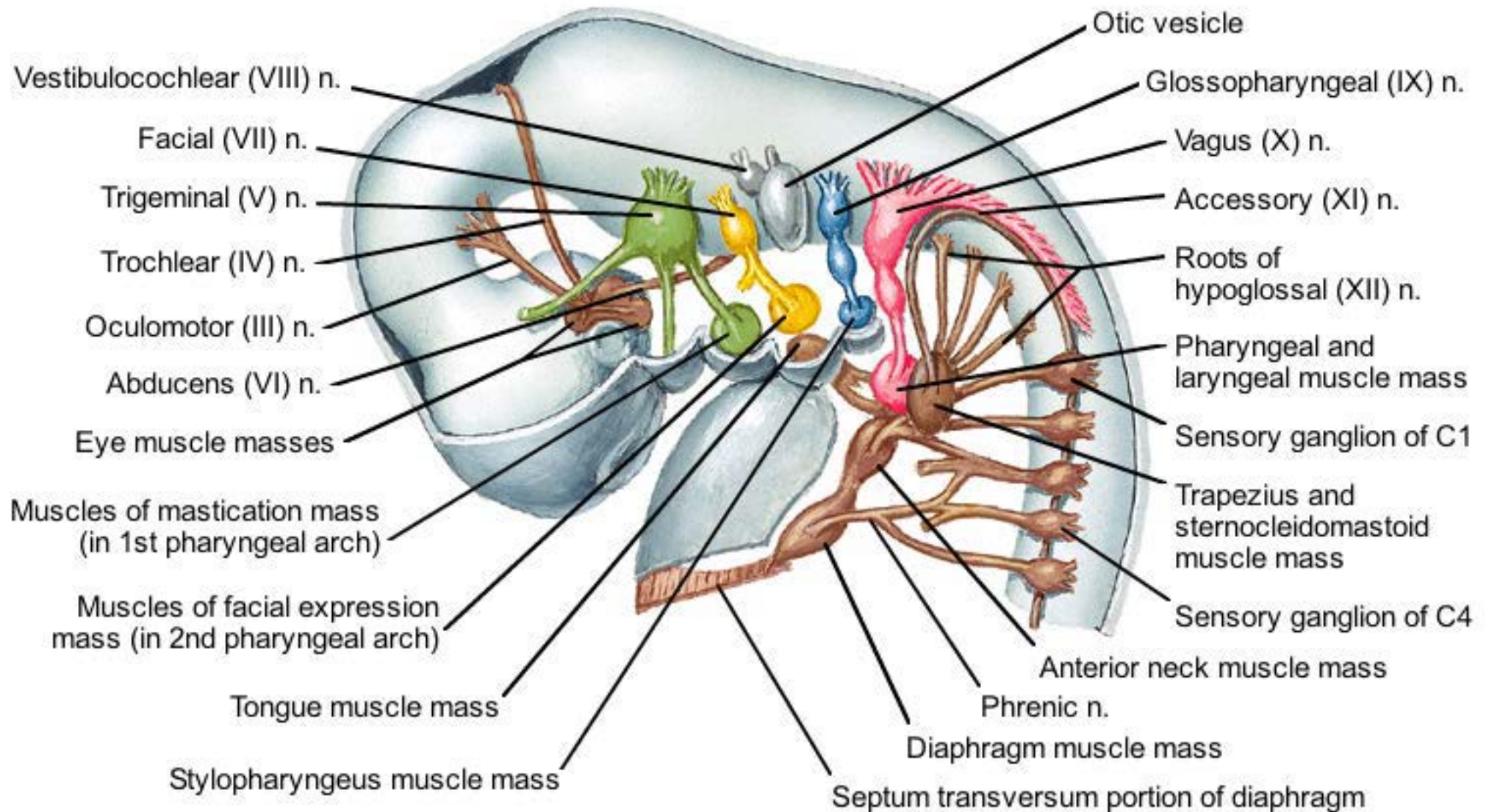


**Cranial nerves:**

- Trigeminal (V1)- Arch 1 (maxillary)
- Trigeminal (V2)- Arch 1 (mandibular)
- Facial (VII)-Arch 2
- Glossopharyngeal- Arch 3
- Vagus (X)-Arches 4 and 6

# Early Development of Pharyngeal Arch Muscle

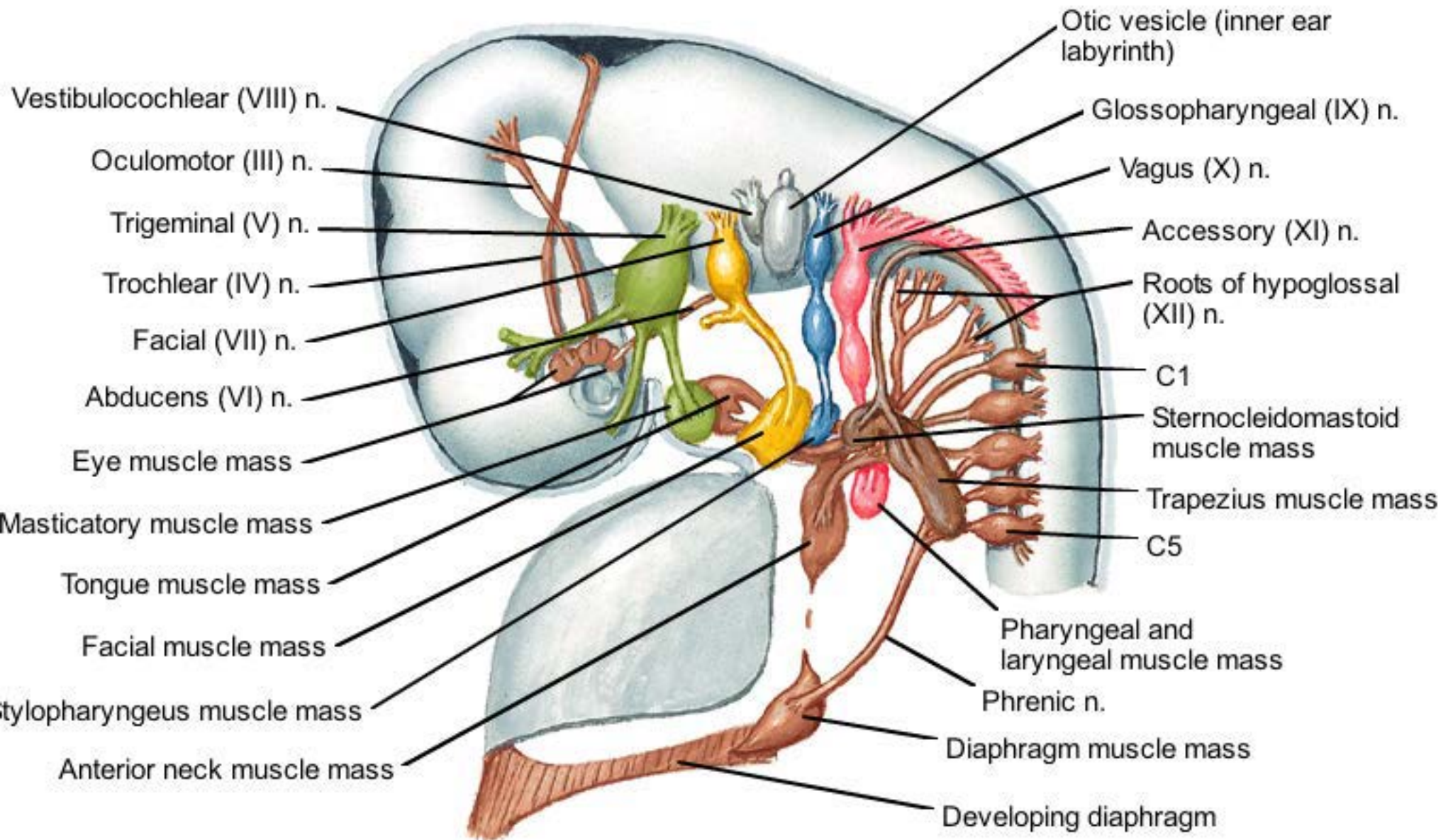
## Origins and innervations of pharyngeal arch and somite myotome muscles at 5 weeks





# Early Development of Pharyngeal Arch Muscle

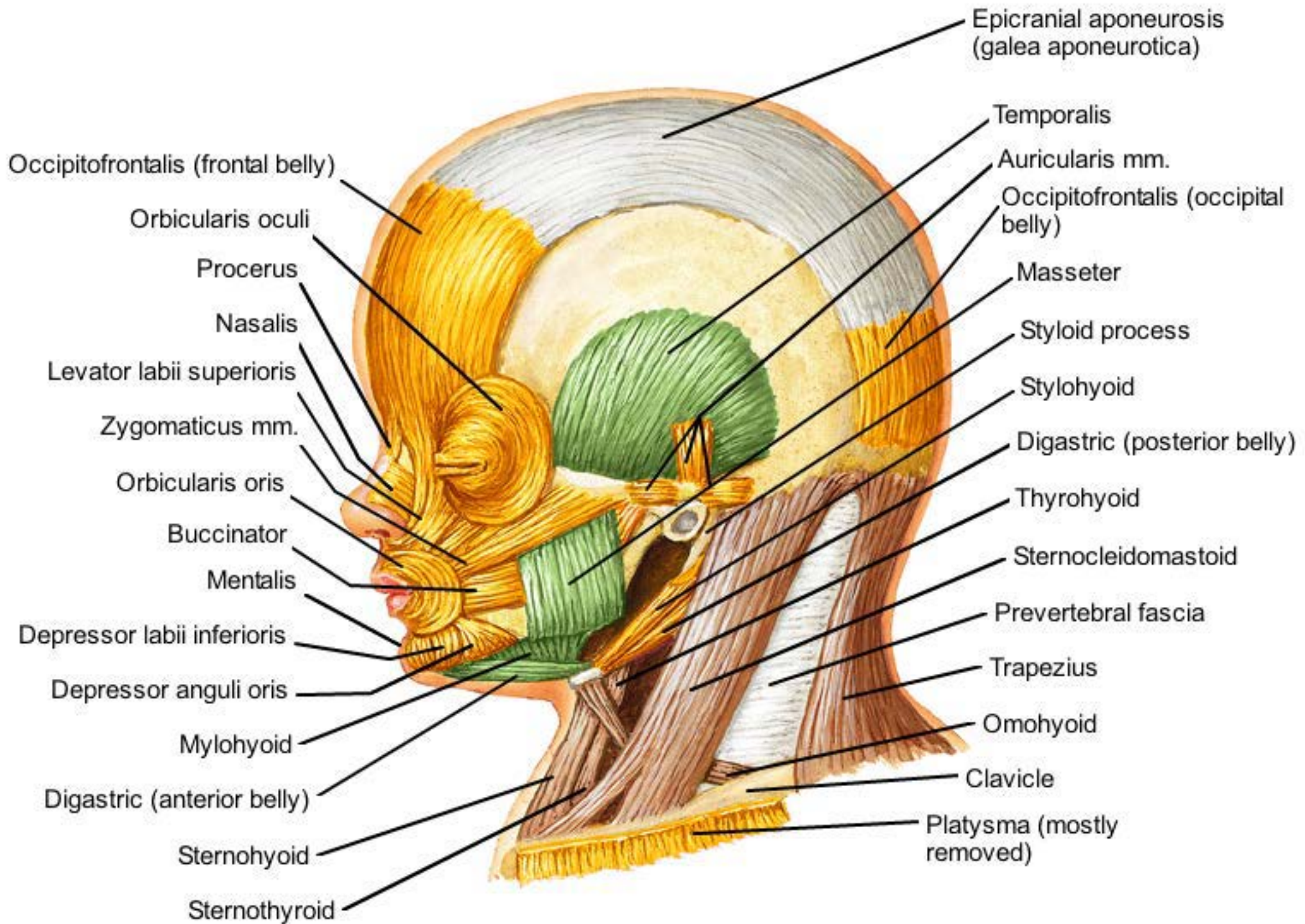
## Origins and innervations of pharyngeal arch and somite myotome muscles at 6 weeks





# Later Development of Pharyngeal Arch Muscles

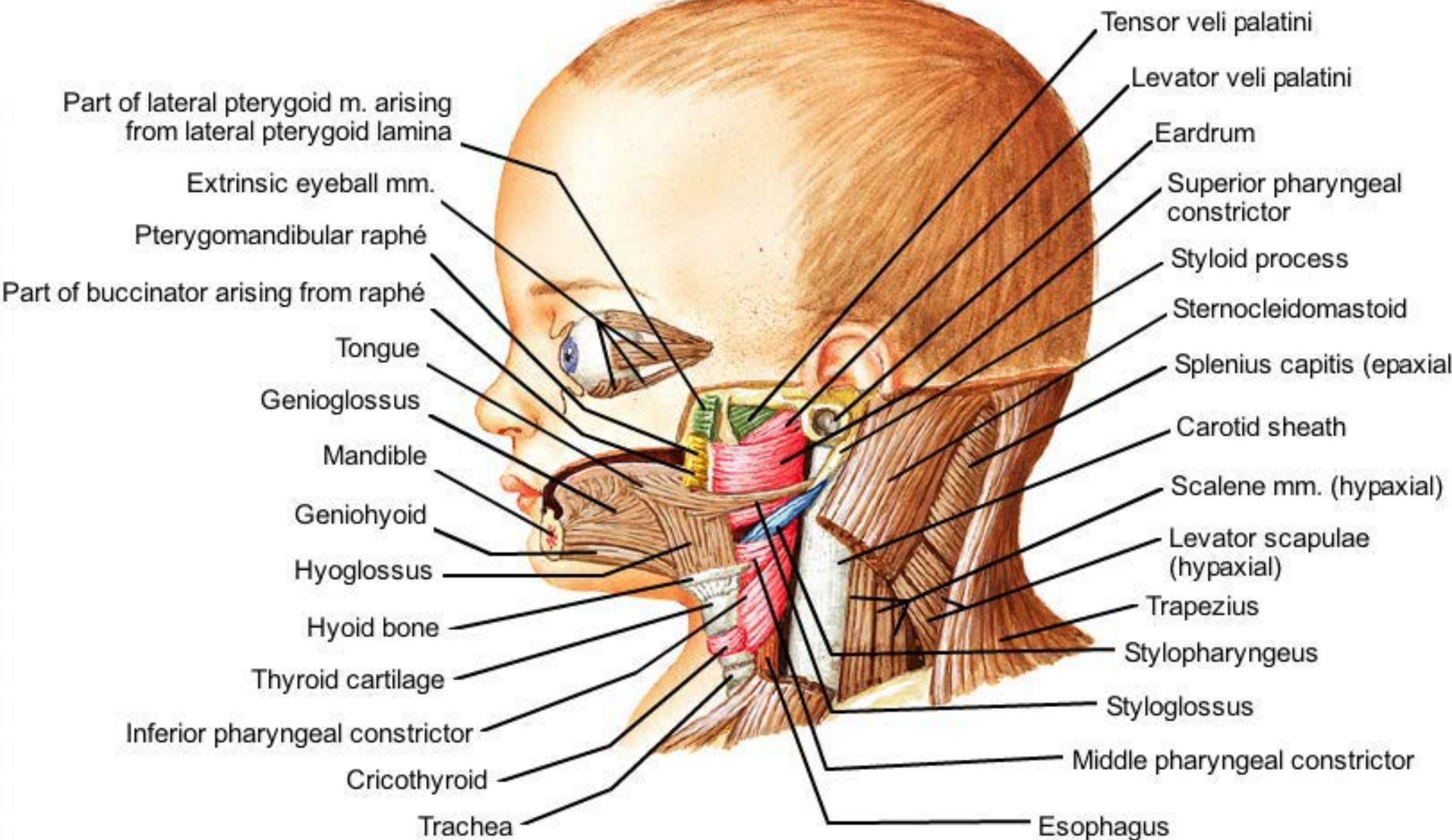
## Superficial muscles





# Later Development of Pharyngeal Arch Muscles

## Deep muscles

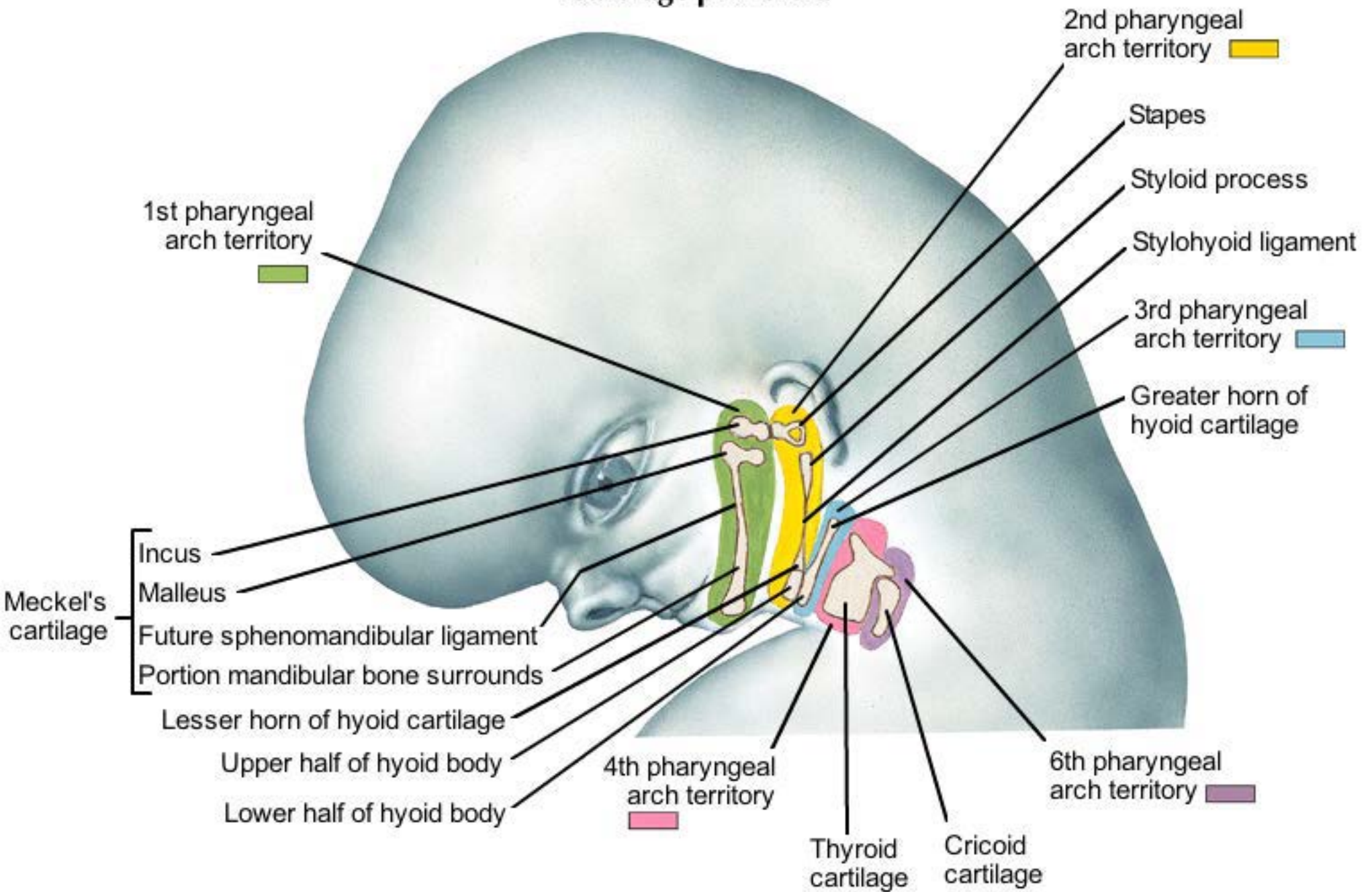




# Pharyngeal Arch Cartilages

Embryo at 7 to 8 weeks

Cartilage primordia



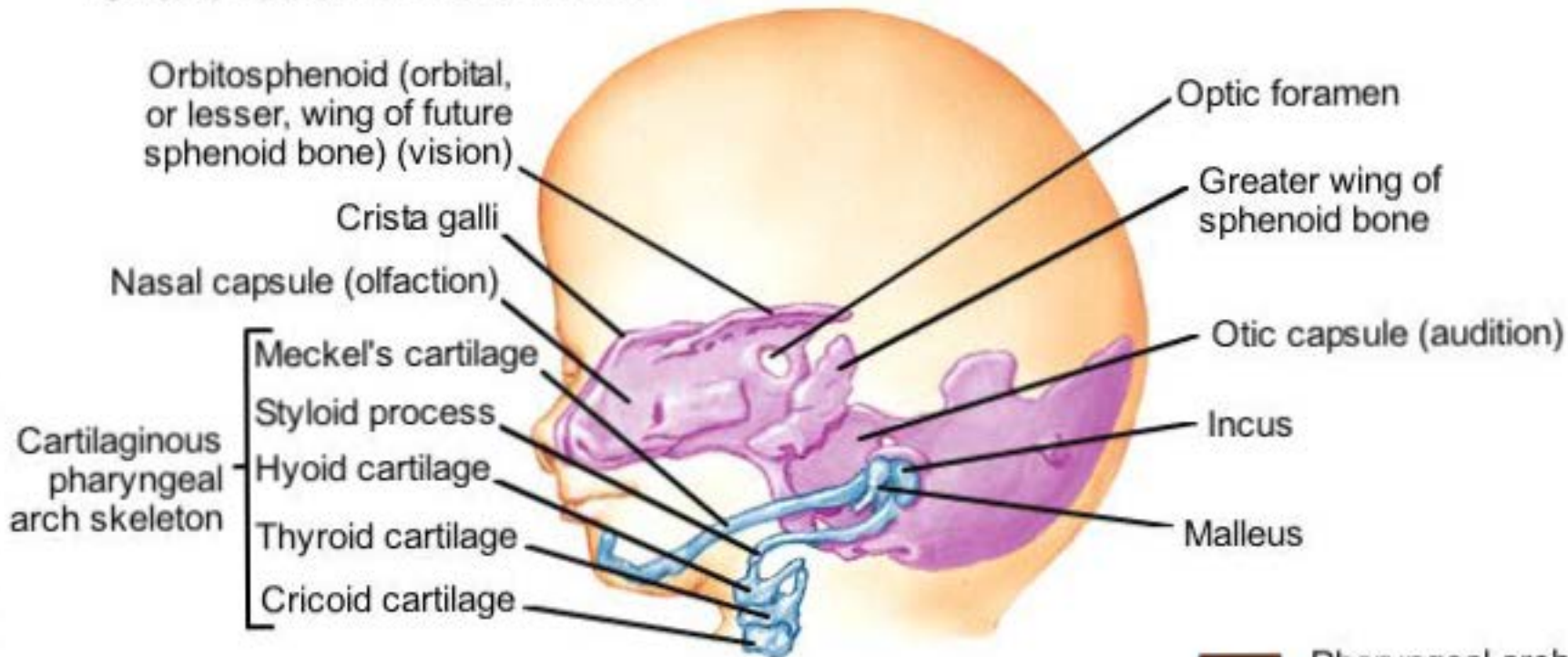
## PHARYNGEAL ARCH BONES AND CARTILAGE

Arch #	Derivatives of Arch Cartilages
1	Malleus, incus, sphenomandibular ligament
2	Stapes, styloid process, stylohyoid ligament, upper half of hyoid
3	Lower half and greater horns of hyoid
4	Thyroid and epiglottic cartilages of larynx
6	Cricoid, arytenoid, and corniculate cartilages of larynx

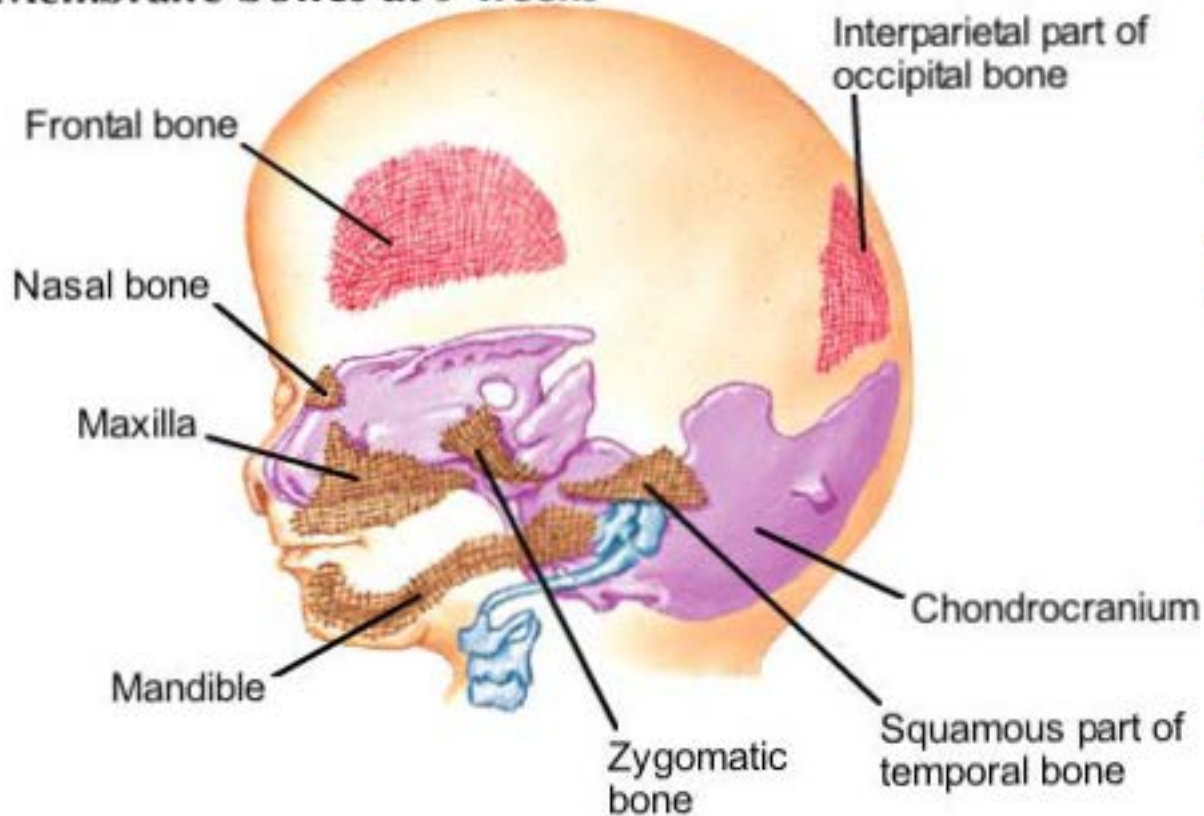






# Ossification of the Skull

## Chondrocranium at 9 weeks



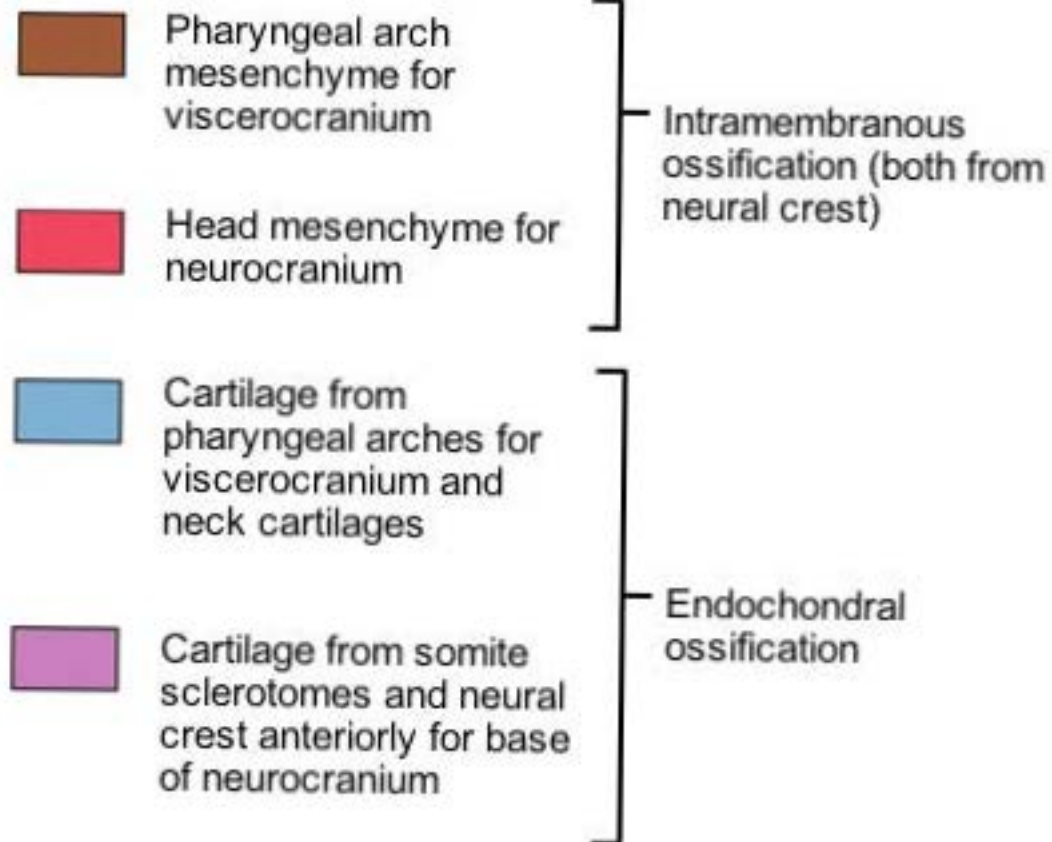
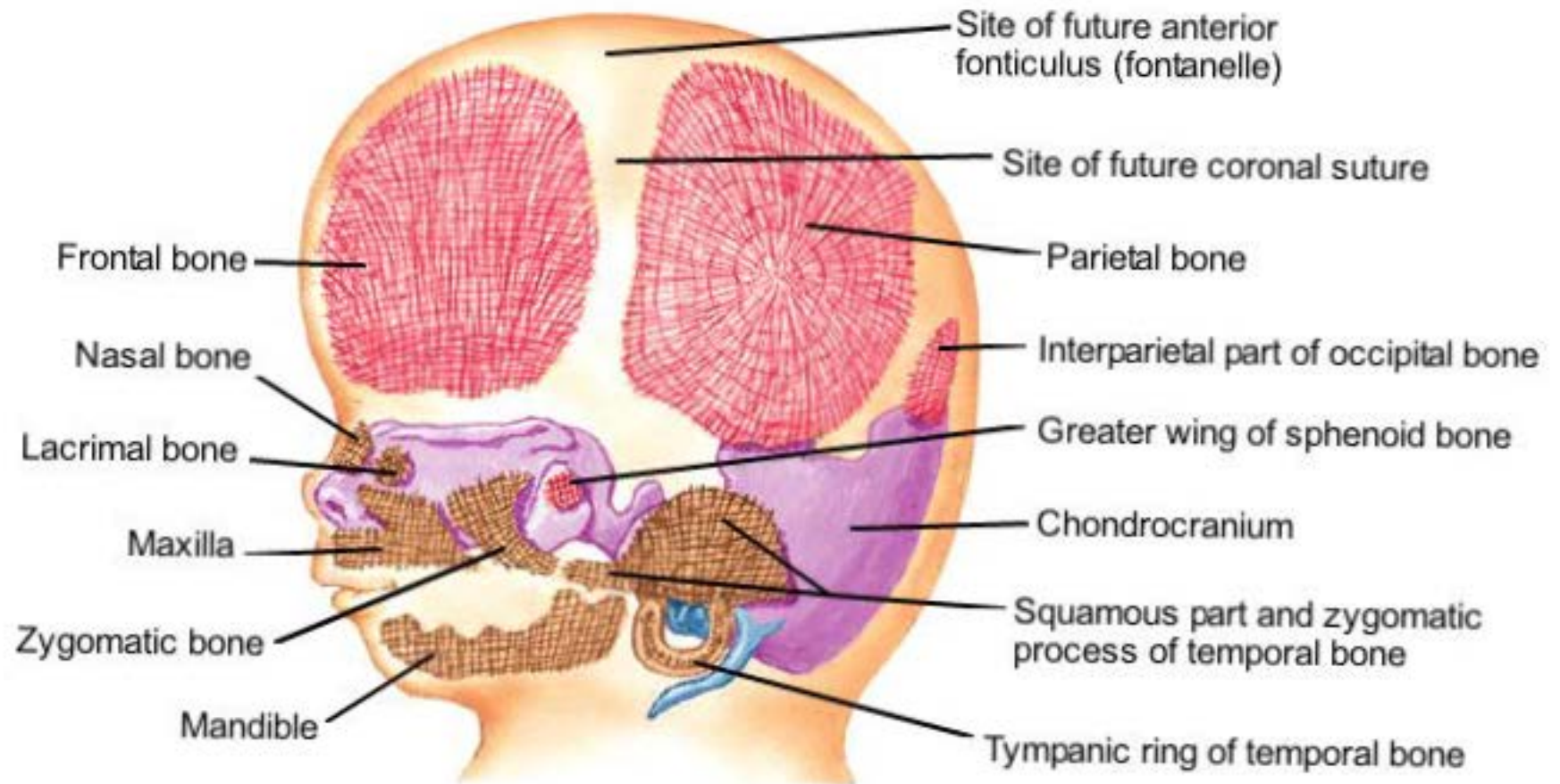
## Membrane bones at 9 weeks



	Pharyngeal arch mesenchyme for viscerocranium	Intramembranous ossification (both from neural crest)
	Head mesenchyme for neurocranium	
	Cartilage from pharyngeal arches for viscerocranium and neck cartilages	Endochondral ossification
	Cartilage from somite sclerotomes and neural crest anteriorly for base of neurocranium	

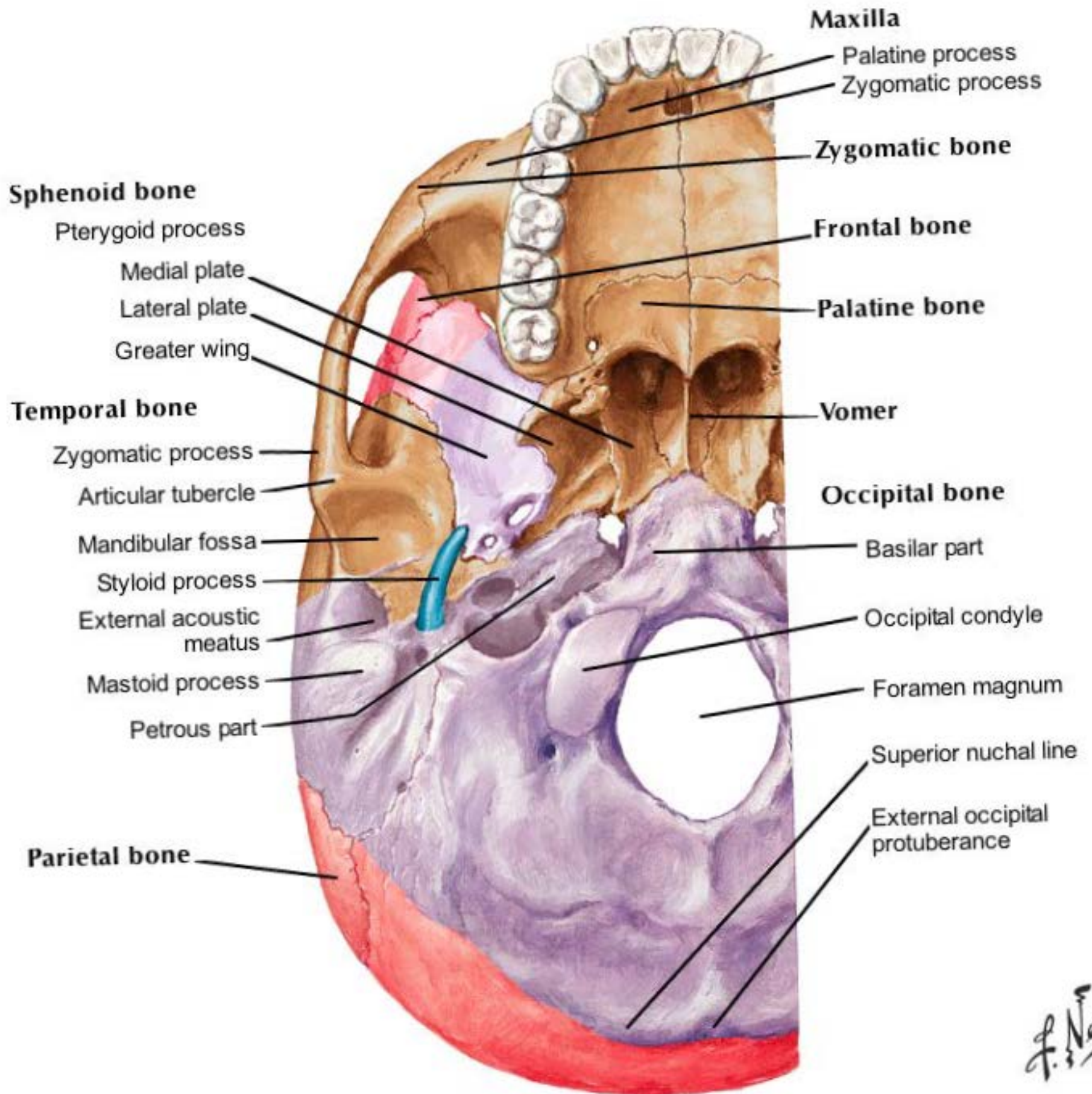
# Ossification of the Skull

## Membrane bones at 12 weeks





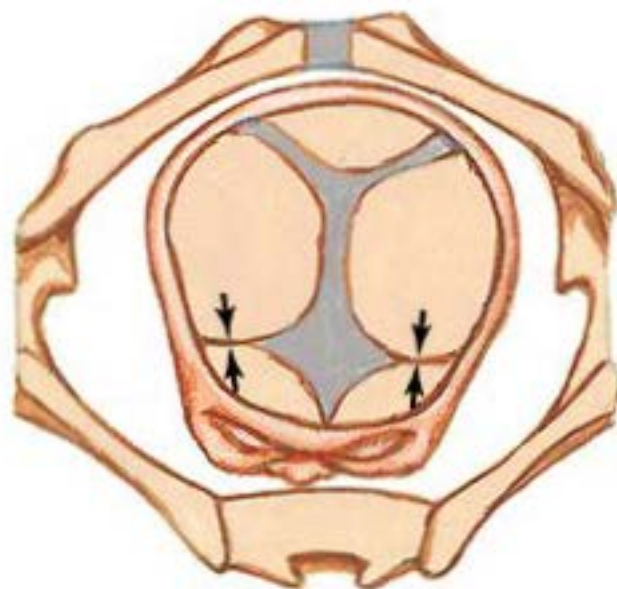
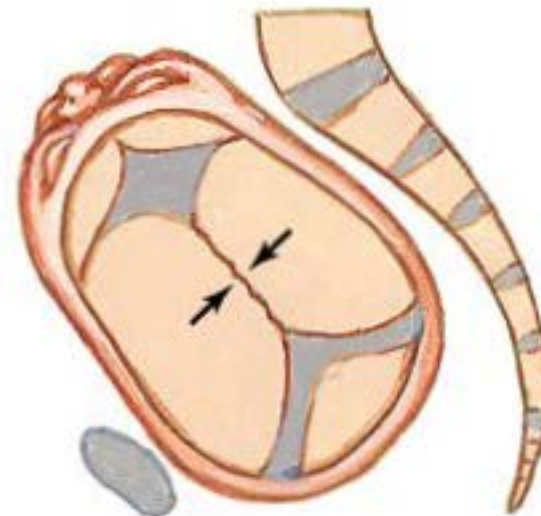
# Ossification of the Skull



# Premature Suture Closure



Scaphocephaly due to sagittal craniosynostosis



Limitation of growth of coronal sutures



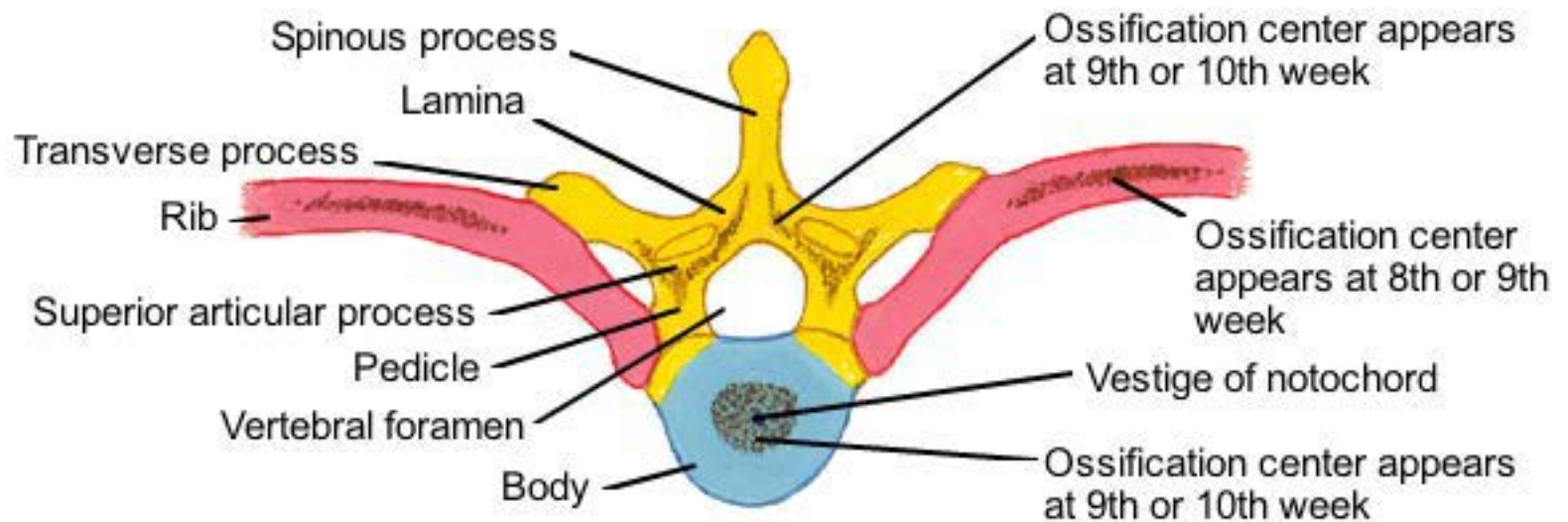
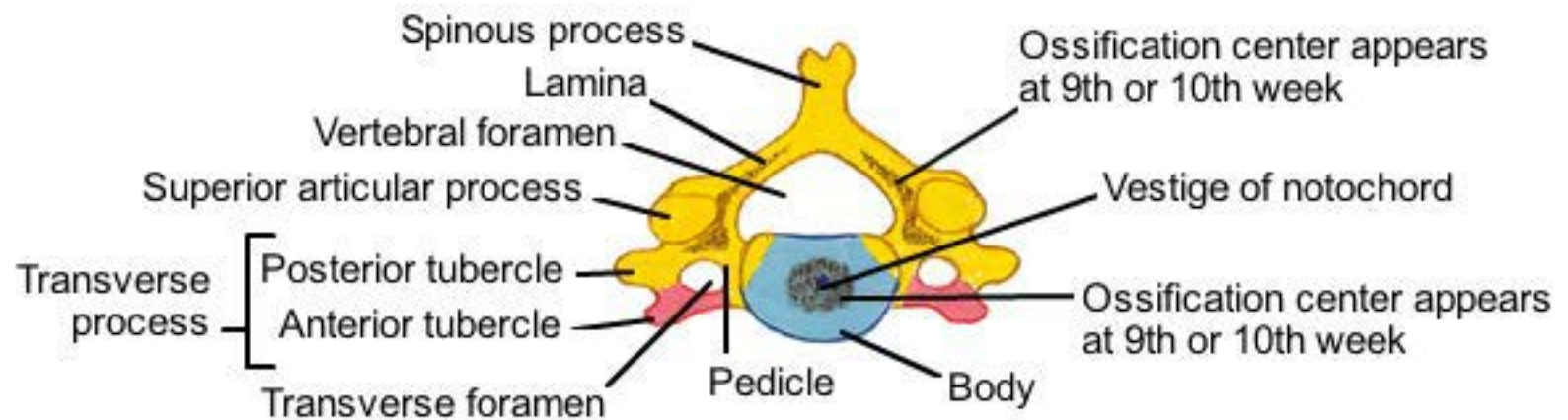
Brachycephaly due to coronal craniosynostosis



# Cervical Ossification

Fate of body, costal process, and neural arch components of cervical and thoracic vertebra, with sites and time of appearance of ossification centers

## Cervical vertebra



### KEY

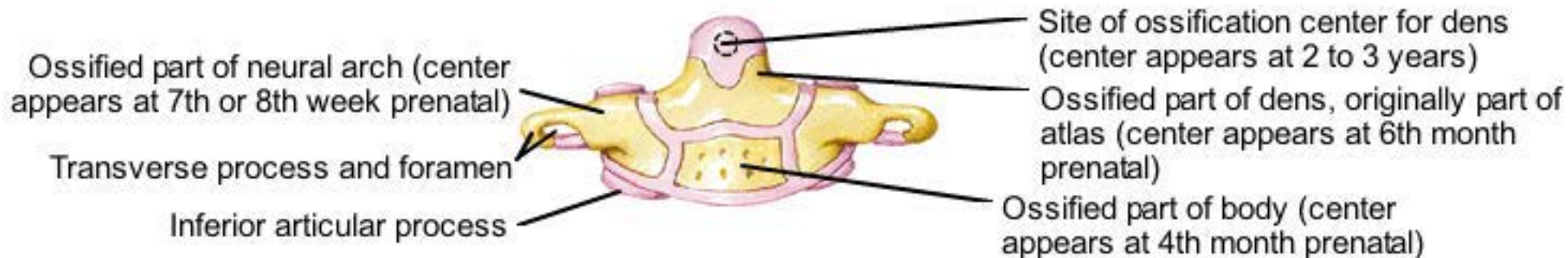
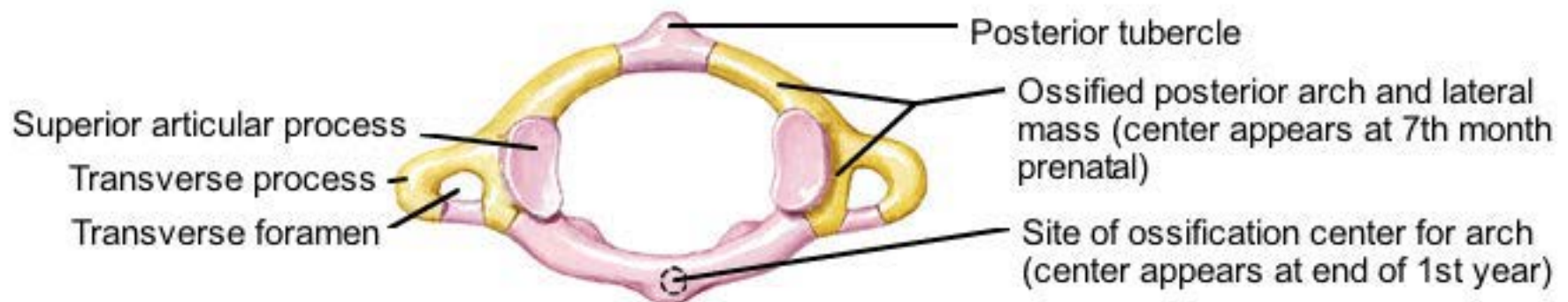
- Body
- Costal process
- Neural arch

## Thoracic vertebra

# Cervical Ossification

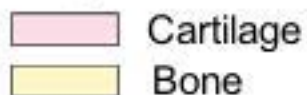
## First and second cervical vertebrae at birth

### 1st cervical vertebra (atlas) (superior view)



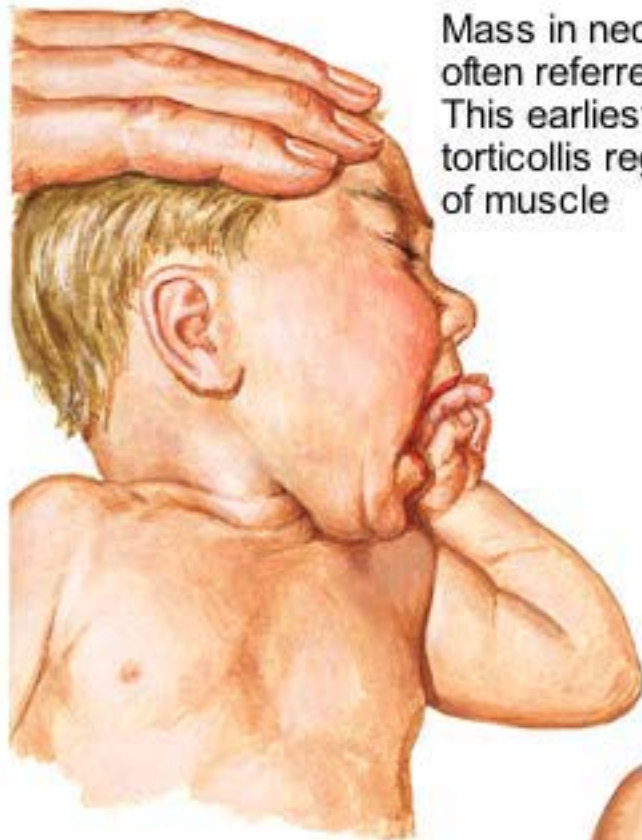
### 2nd cervical vertebra (axis) (anterior view)

#### Key





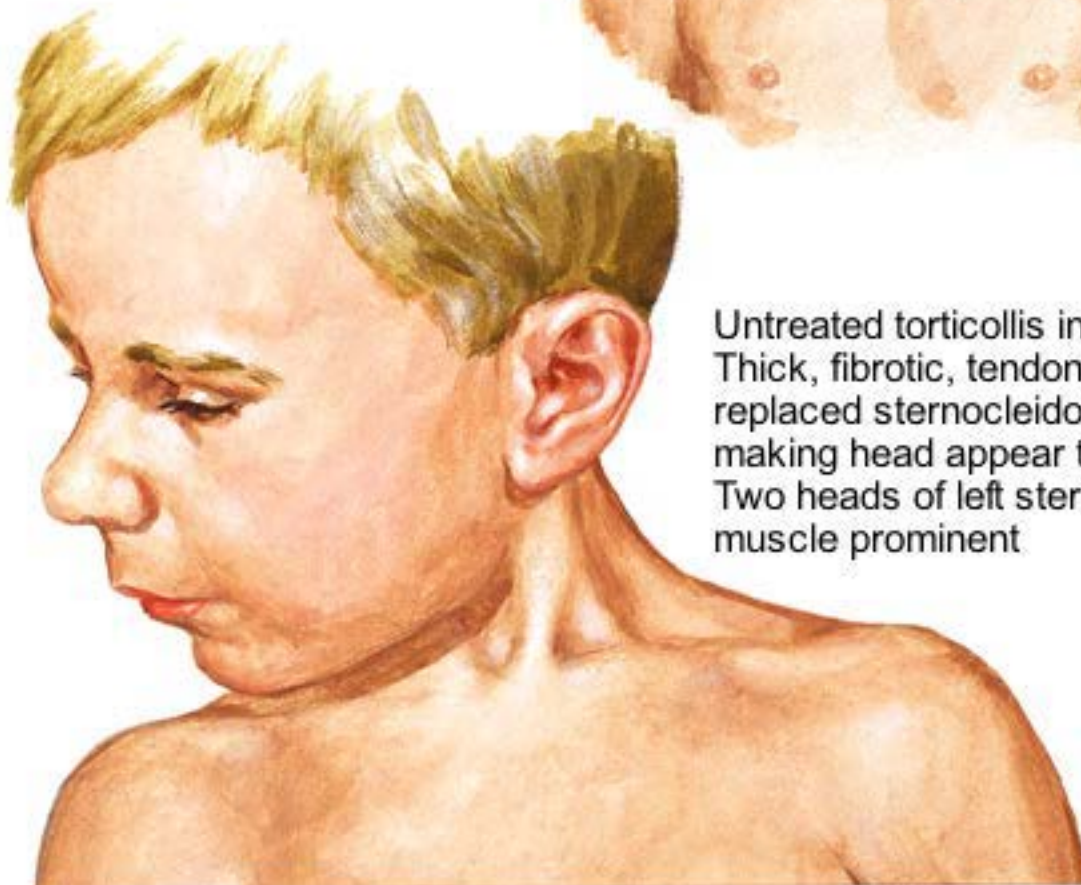
# Torticollis



Mass in neck within sternocleidomastoid muscle often referred to as sternocleidomastoid tumor. This earliest manifestation of congenital muscular torticollis regresses, to be followed by contracture of muscle



Child with muscular torticollis. Head tilted to left with chin turned slightly to right because of contracture of left sternocleidomastoid muscle. Note facial symmetry (flattening of left side of face)



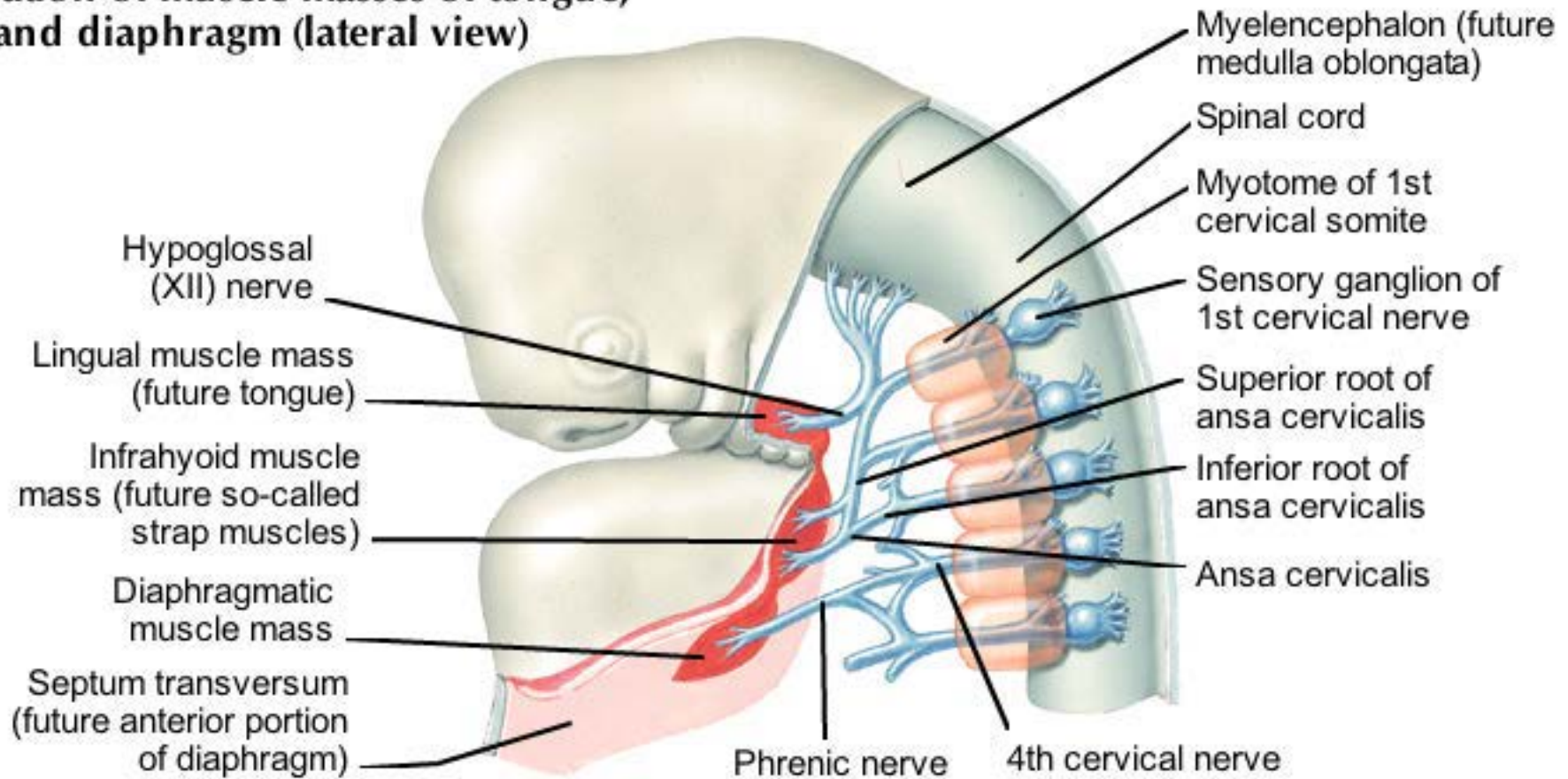
Untreated torticollis in 5-year-old boy. Thick, fibrotic, tendonlike bands have replaced sternocleidomastoid muscle, making head appear tethered to clavicle. Two heads of left sternocleidomastoid muscle prominent



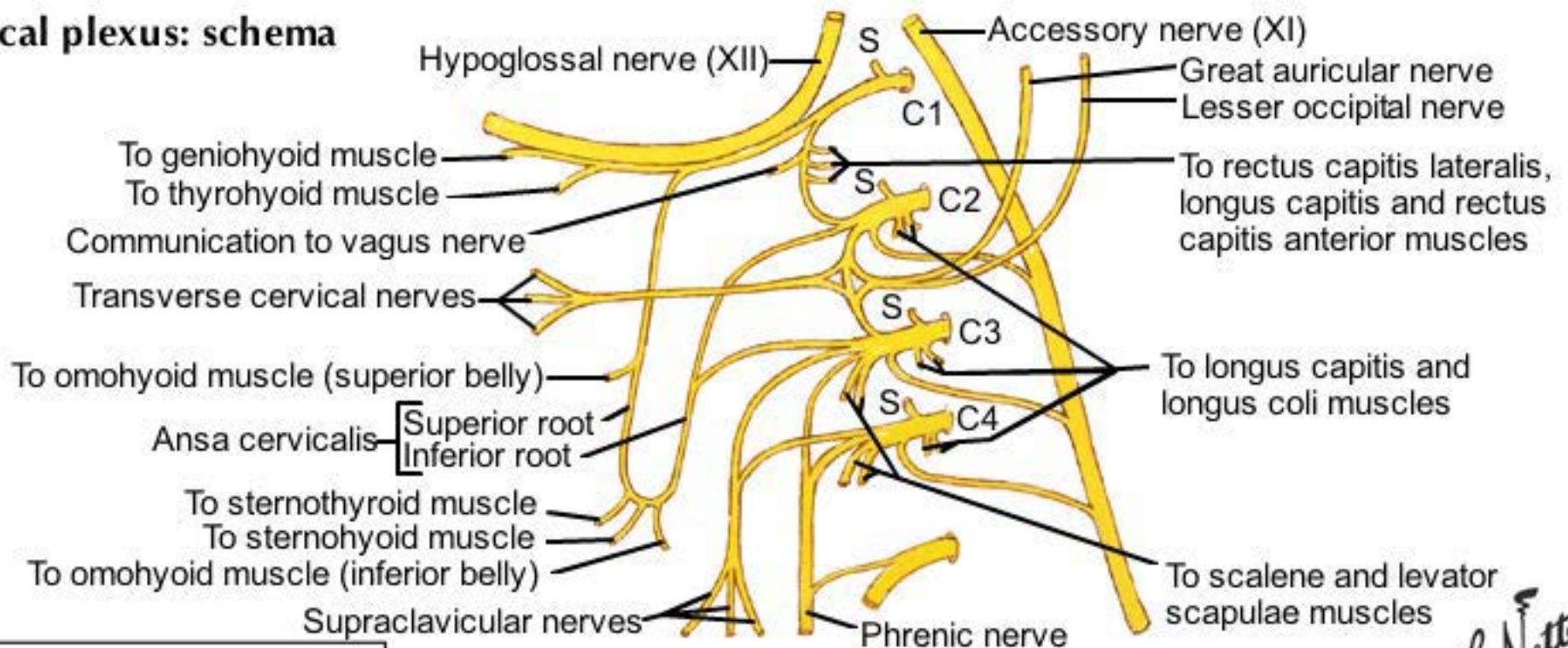
# Cervical Plexus

The cervical plexus and hypoglossal nerve in a 5- to 6-week embryo

Innervation of muscle masses of tongue, neck, and diaphragm (lateral view)



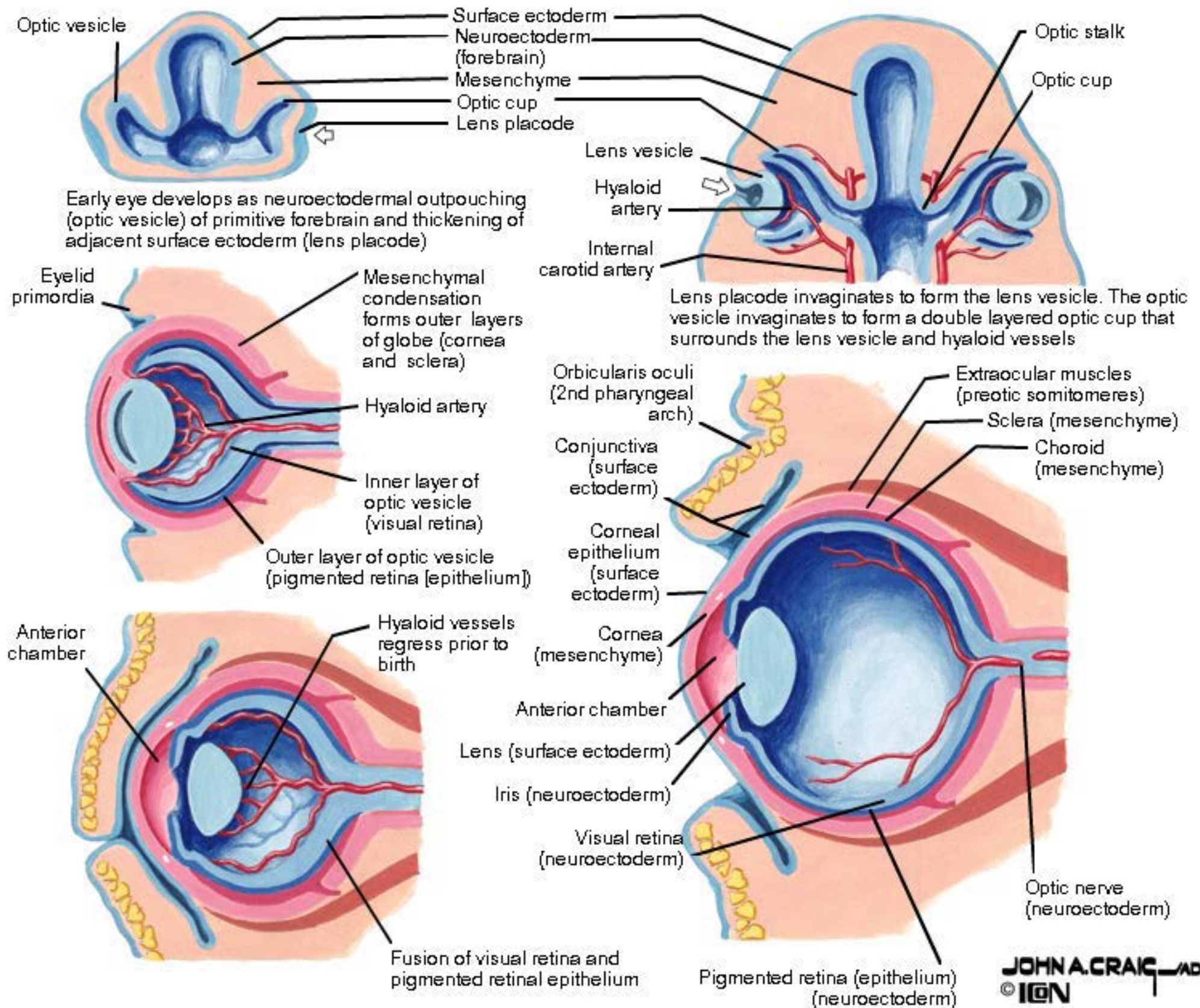
## Cervical plexus: schema



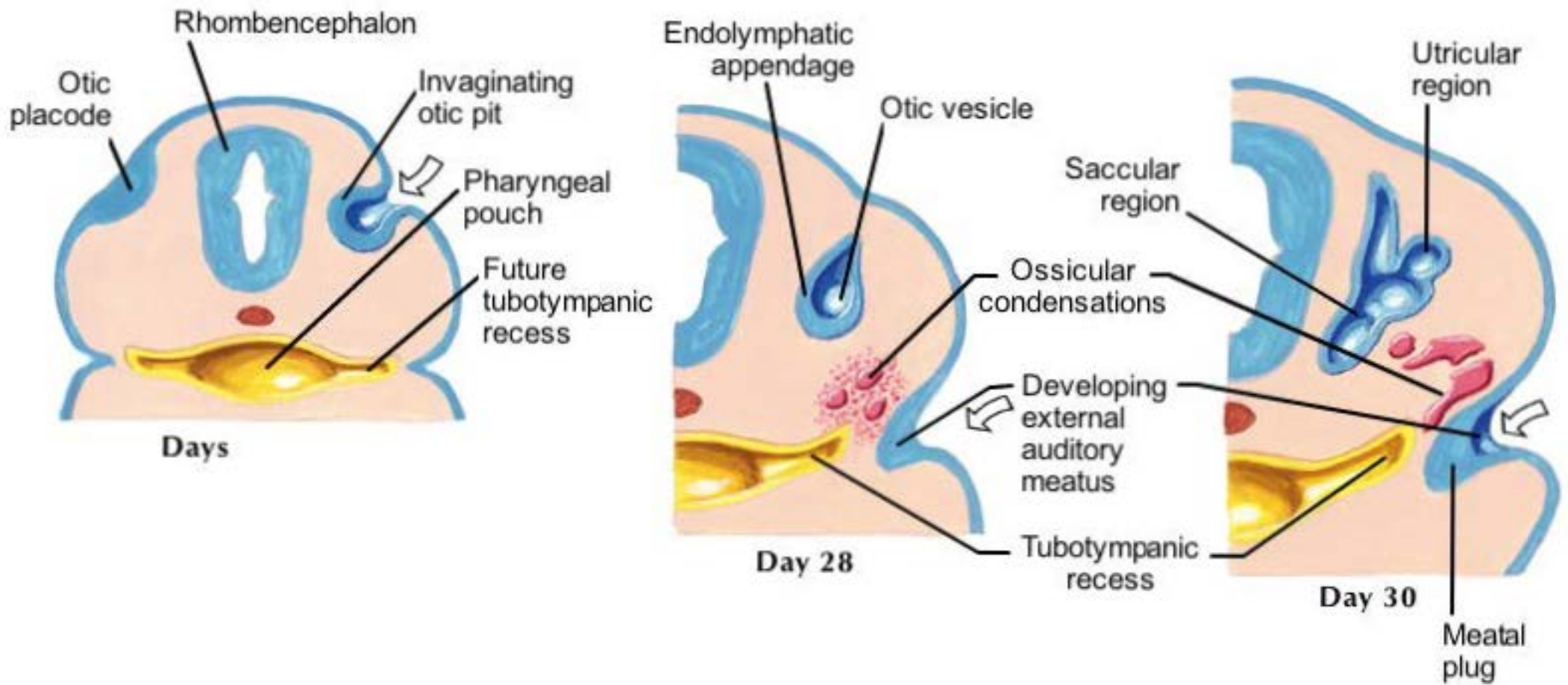
**Note:**  
S = 5 Gray ramus from superior cervical sympathetic ganglion



# Orbit

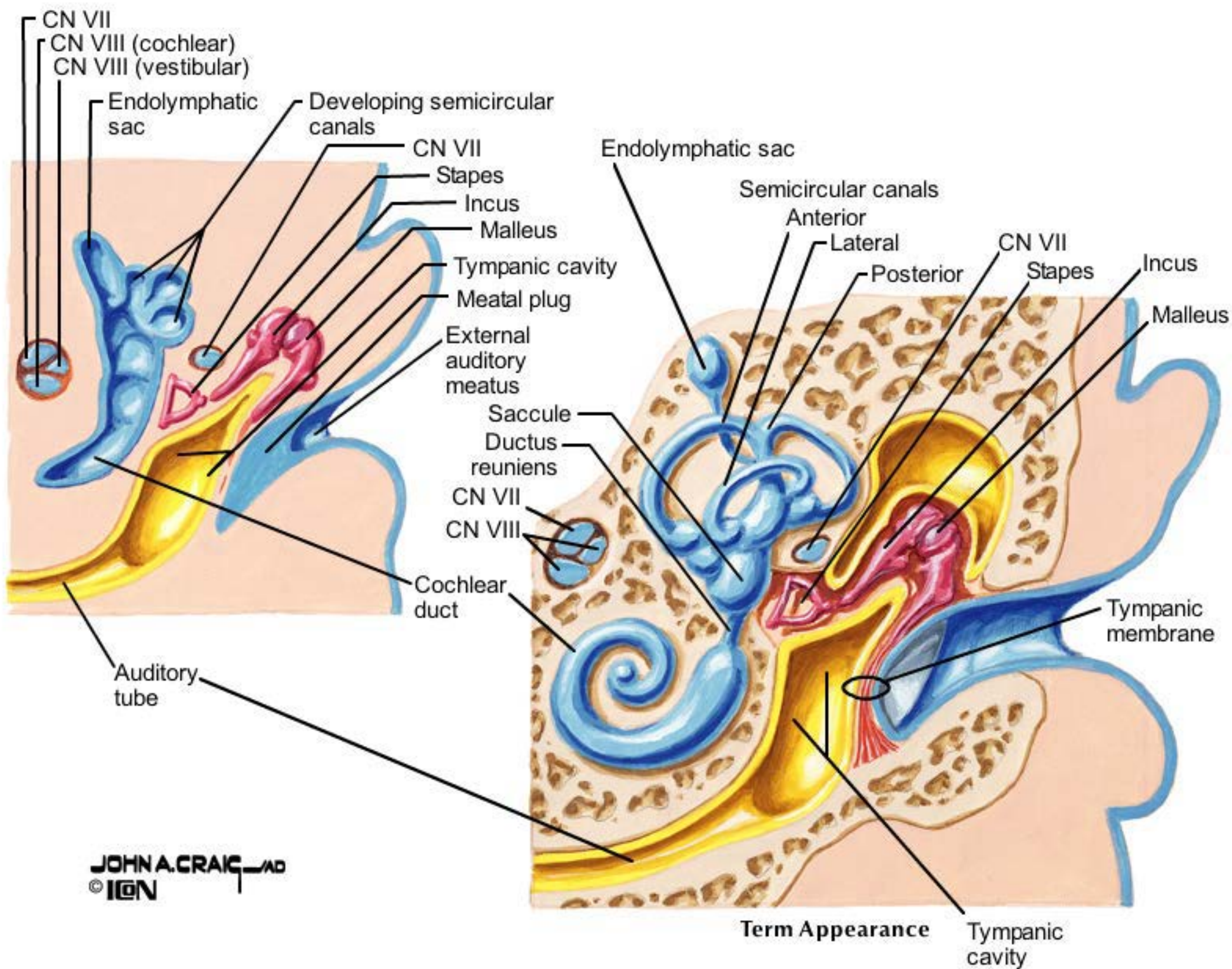


# Ear Development





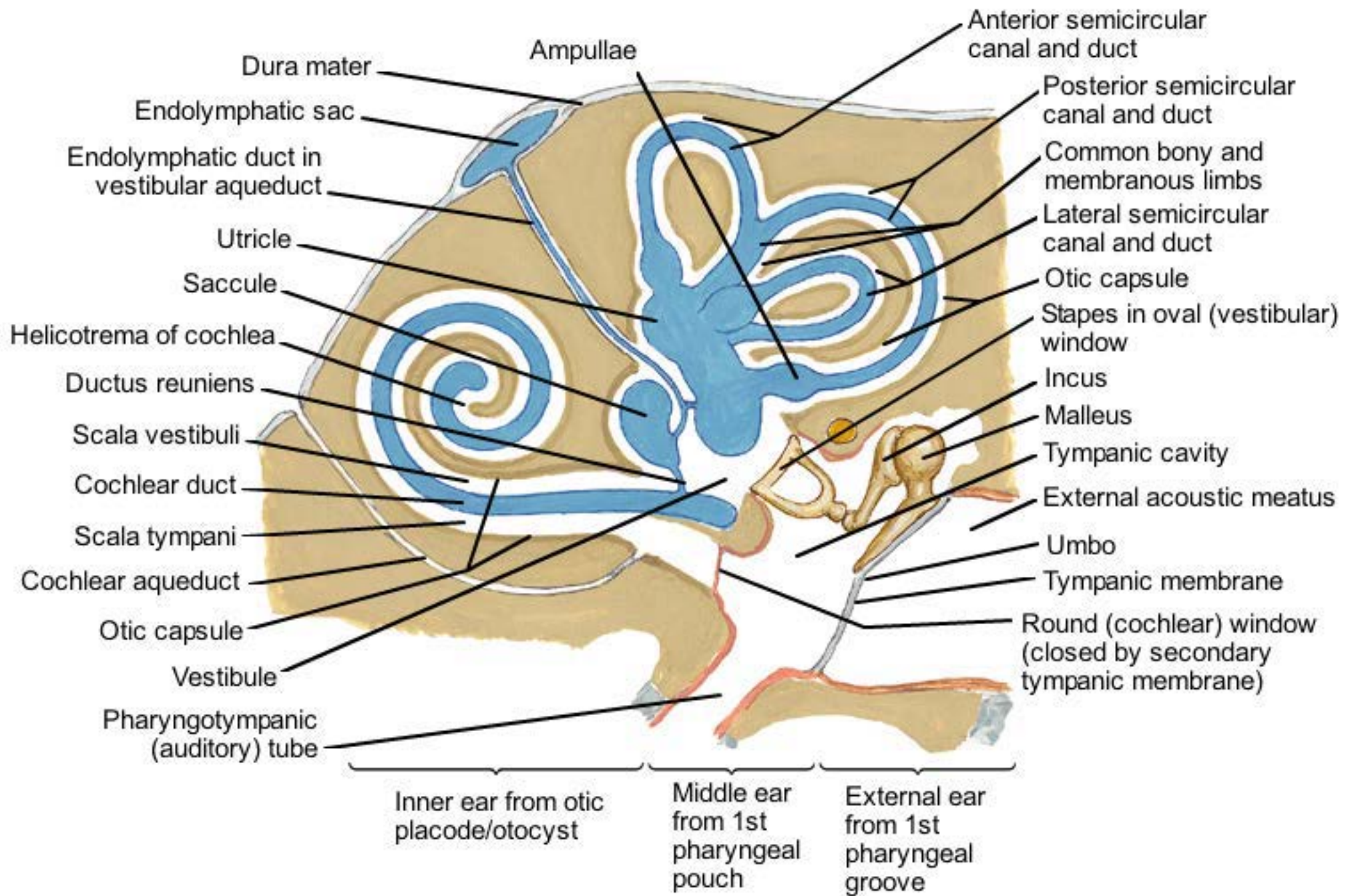
# Ear Development





# Adult Ear Organization

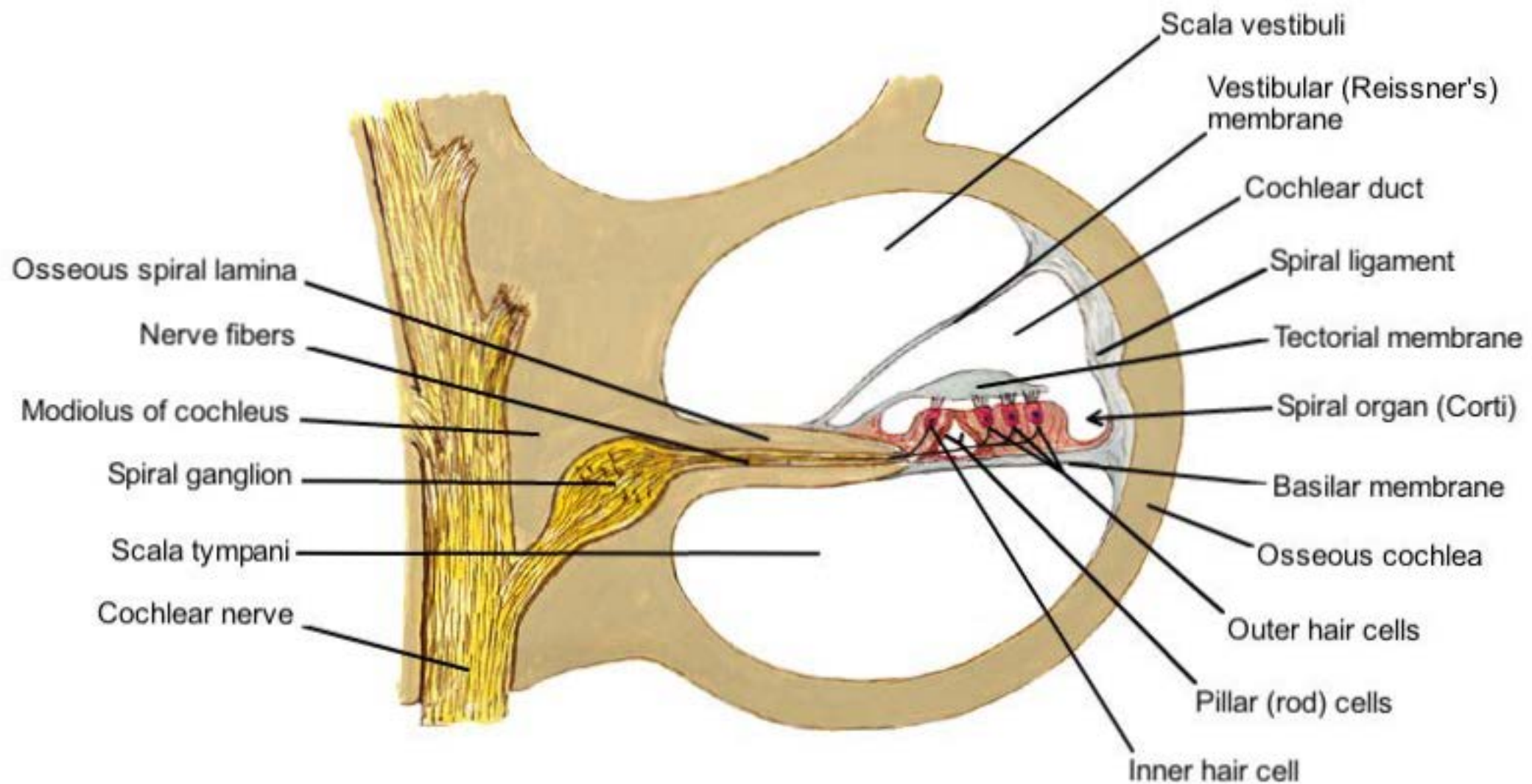
## Bony and membranous labyrinths: schema





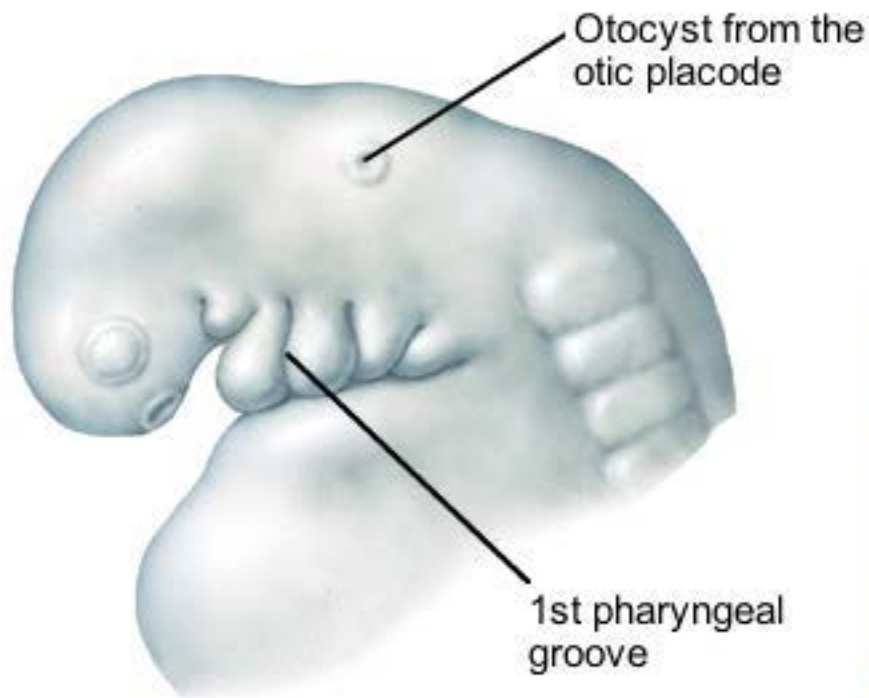
## Adult Ear Organization

### Section through turn of cochlea

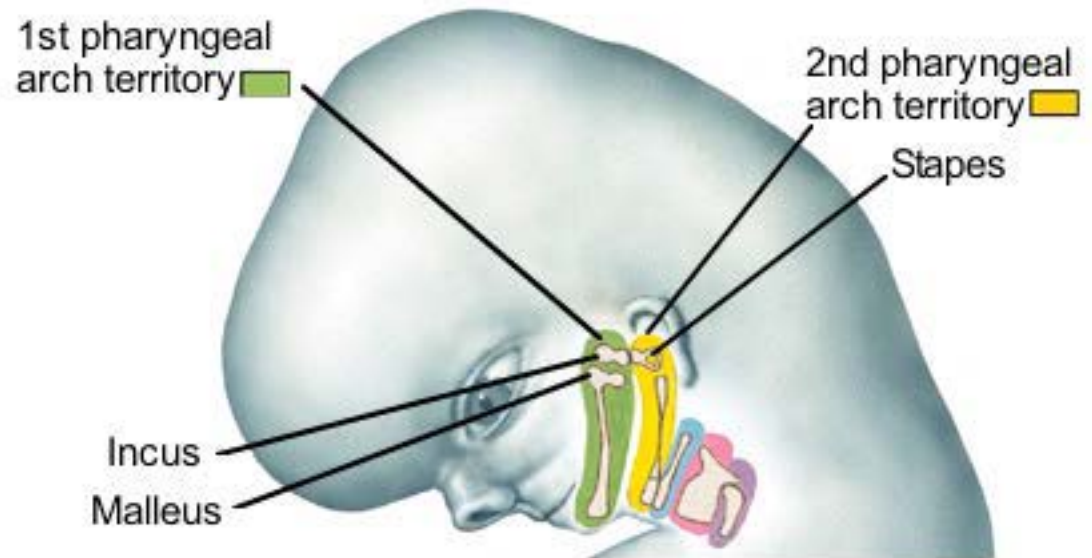
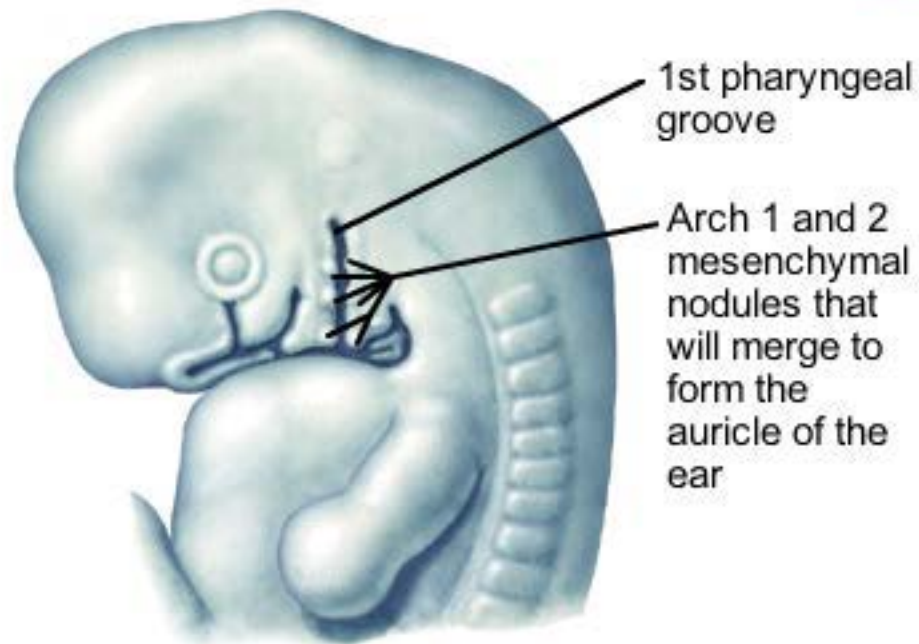
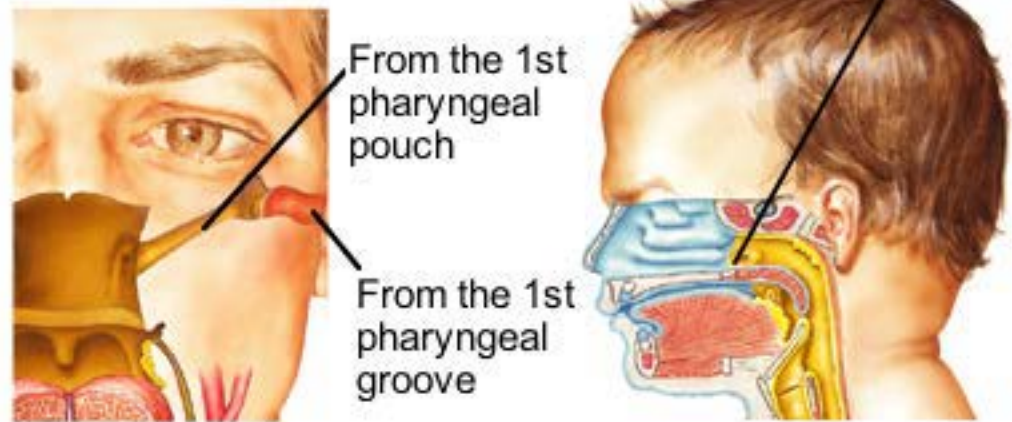


# Summary of Ear Development

## Primordia of the outer, middle, and inner ear

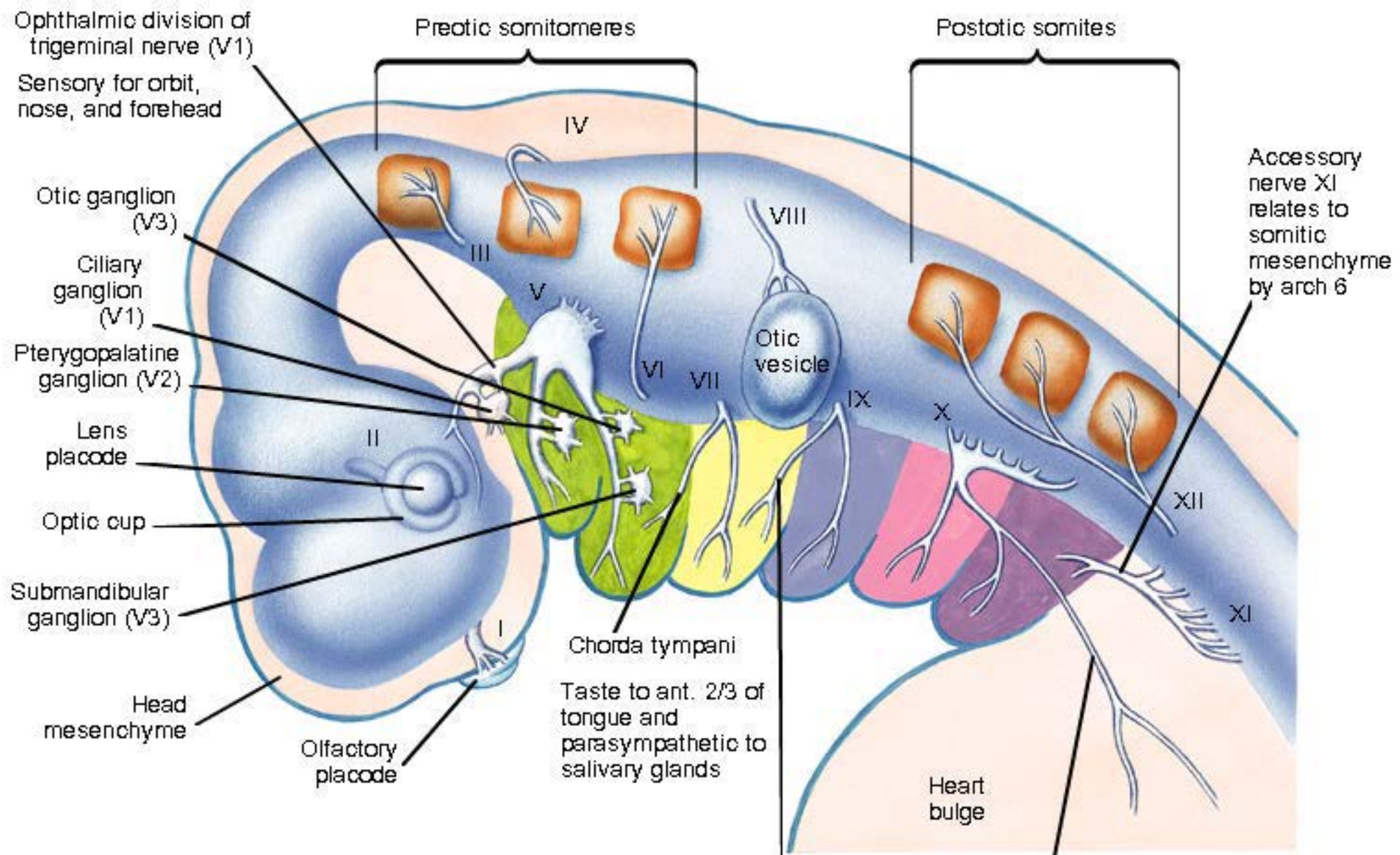


Ostium of right auditory tube leading to the middle ear cavity and mastoid air cells (all from 1st pharyngeal pouch)





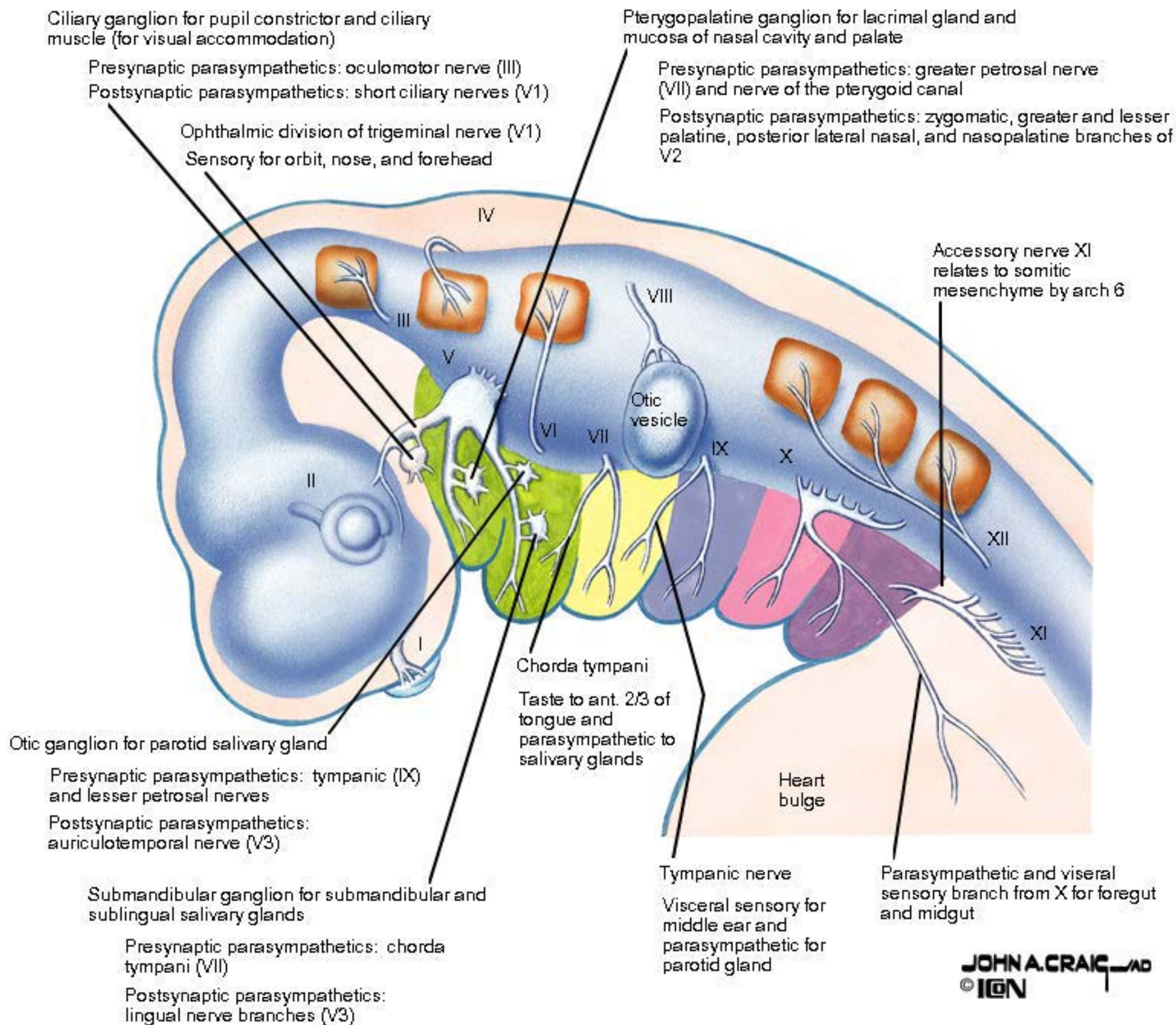
# Cranial Nerve Primordia



JOHN A. CRAIG MD  
© IGCN



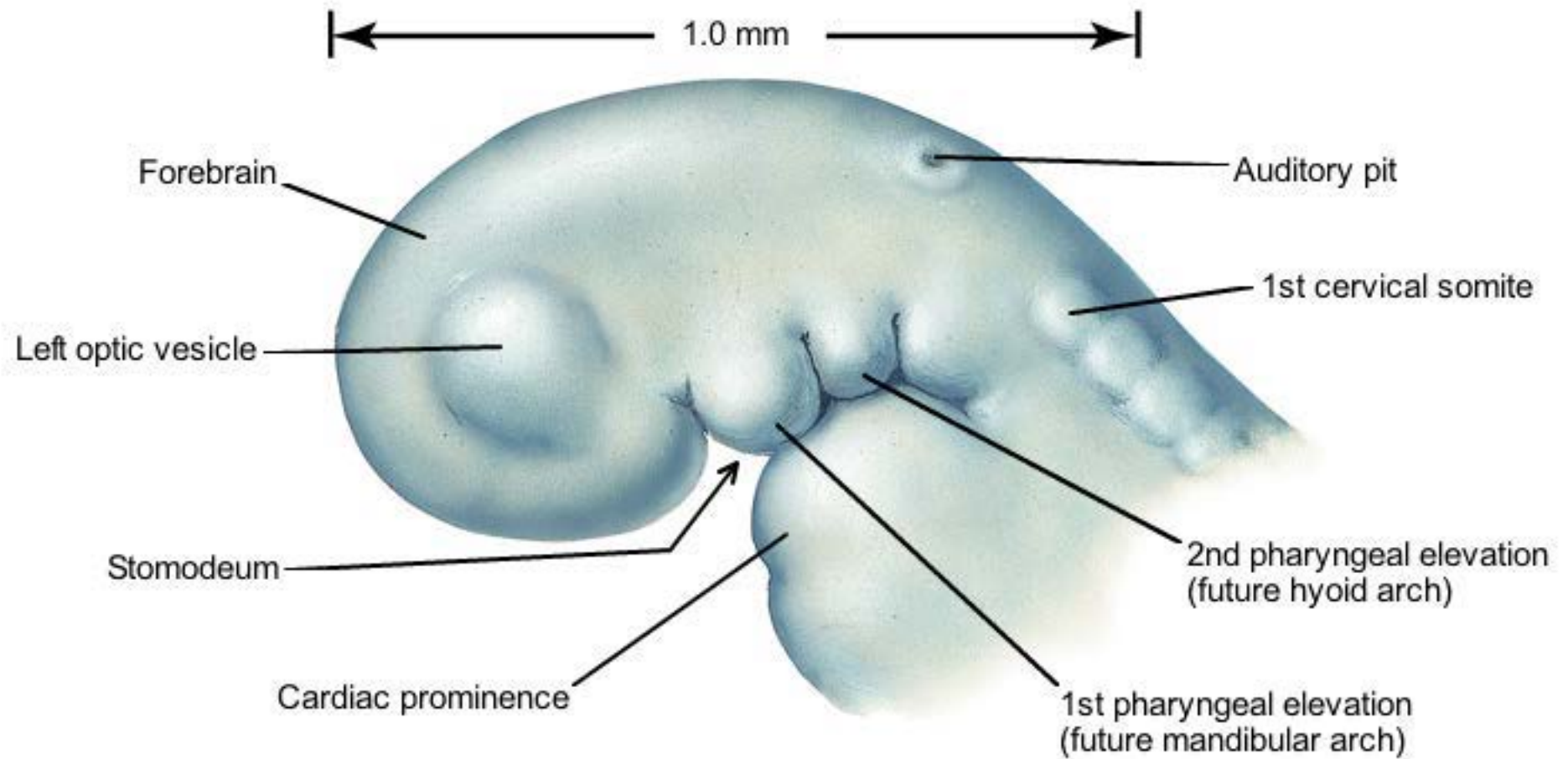
# Parasympathetic Innervation and Unique Nerves





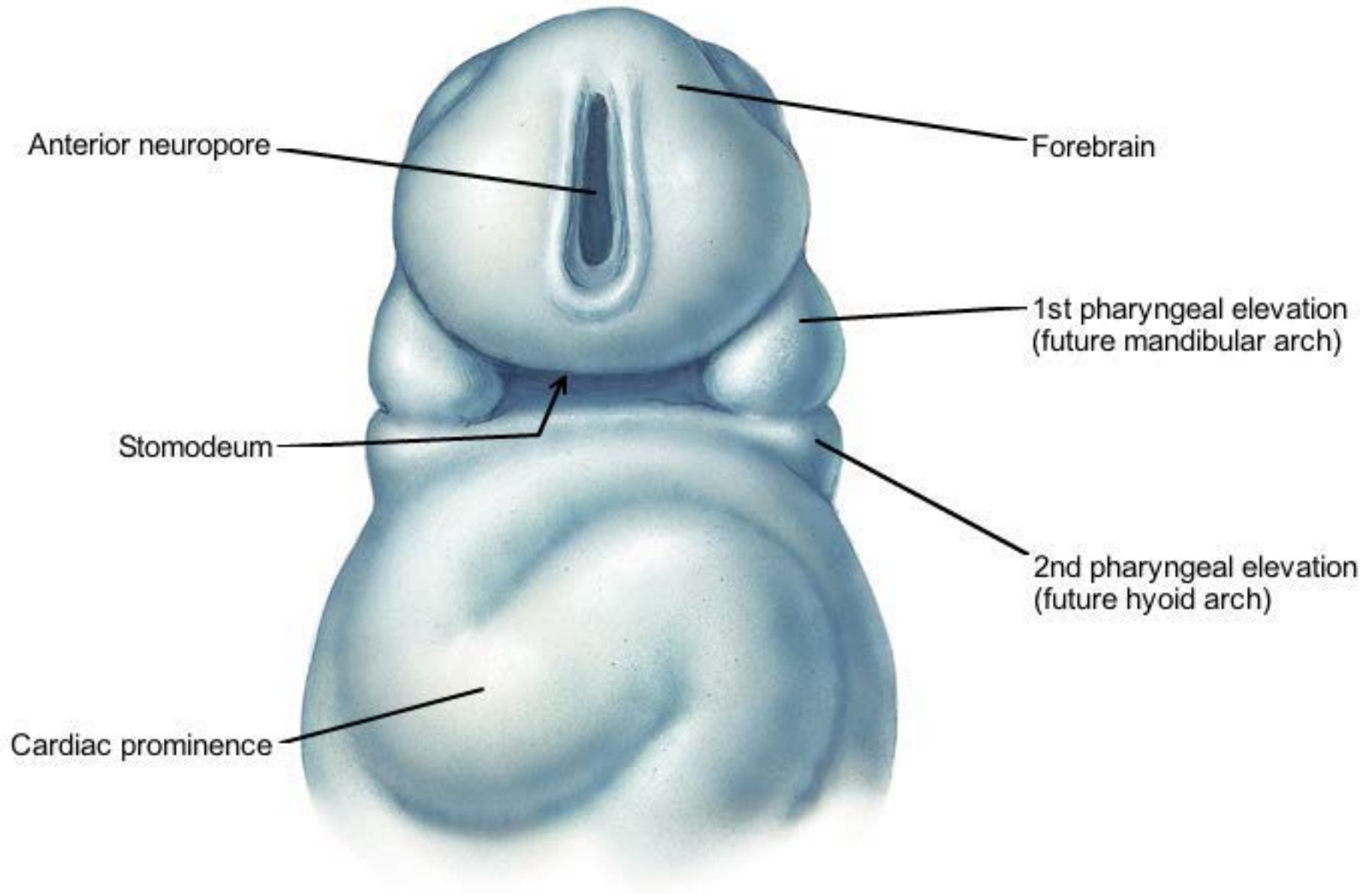
# Development of the Face: 3 to 4 Weeks

Lateral view



# Development of the Face: 3 to 4 Weeks

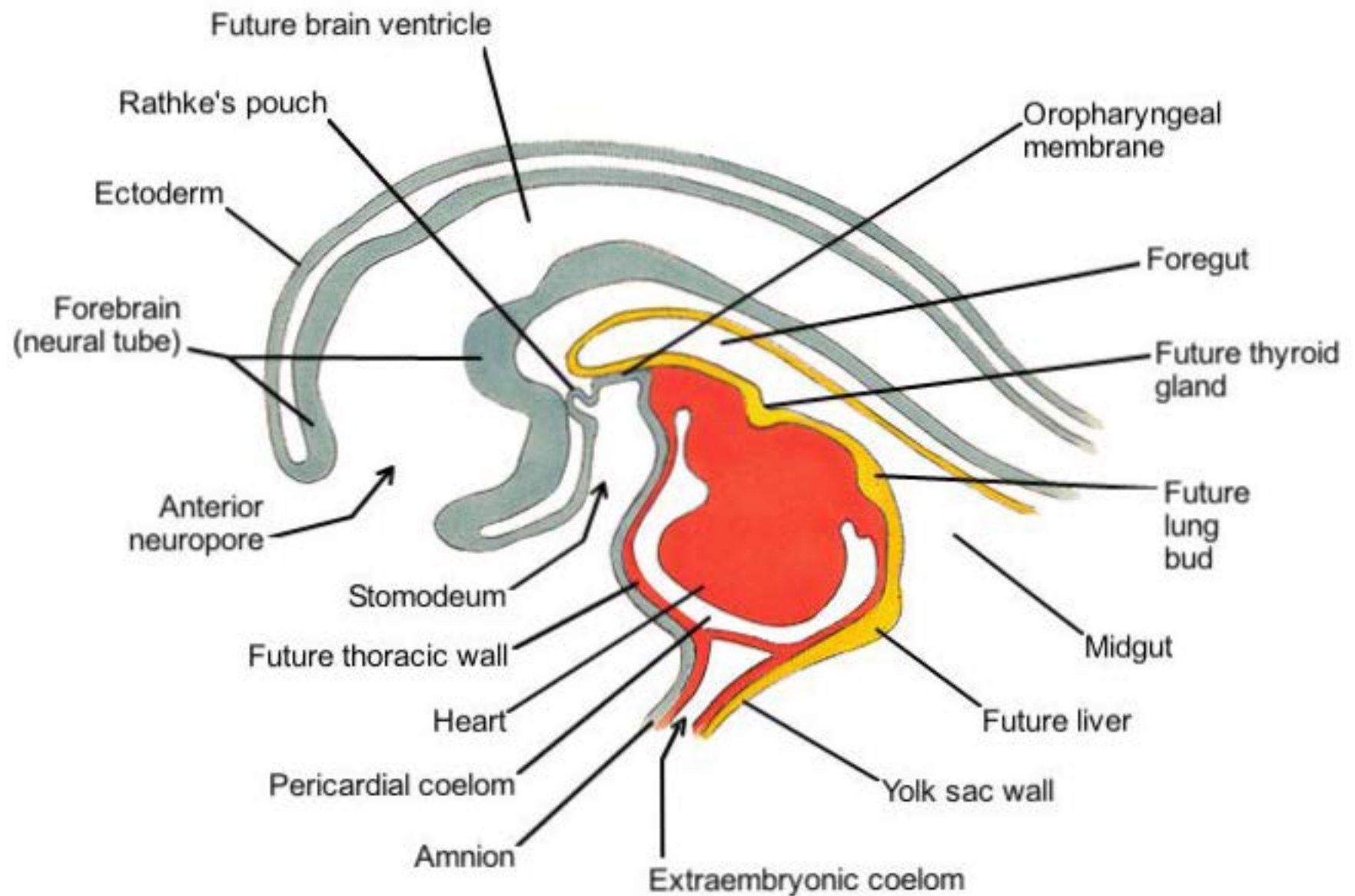
## Lateral view





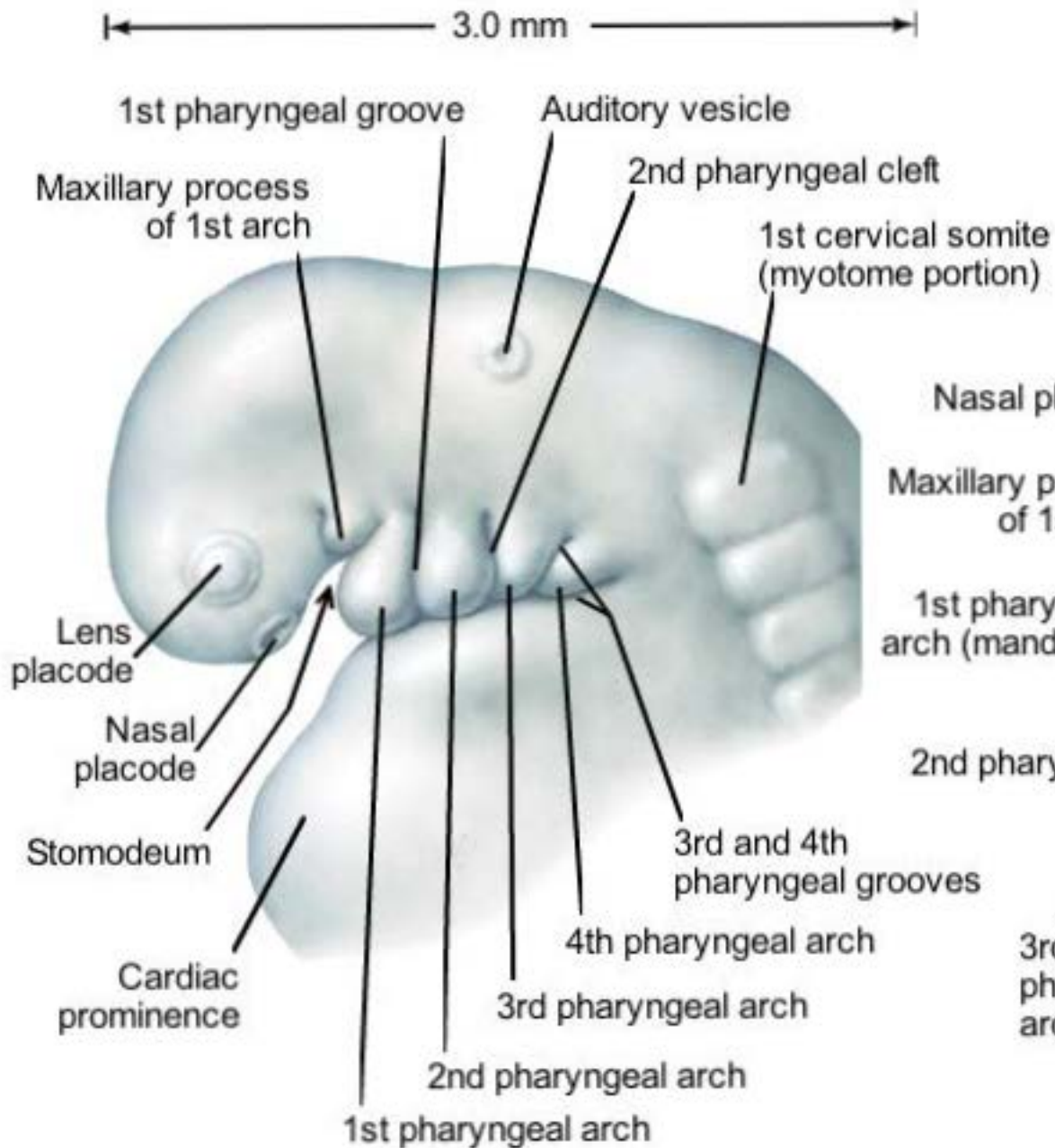
# Development of the Face: 3 to 4 Weeks

## Sagittal section

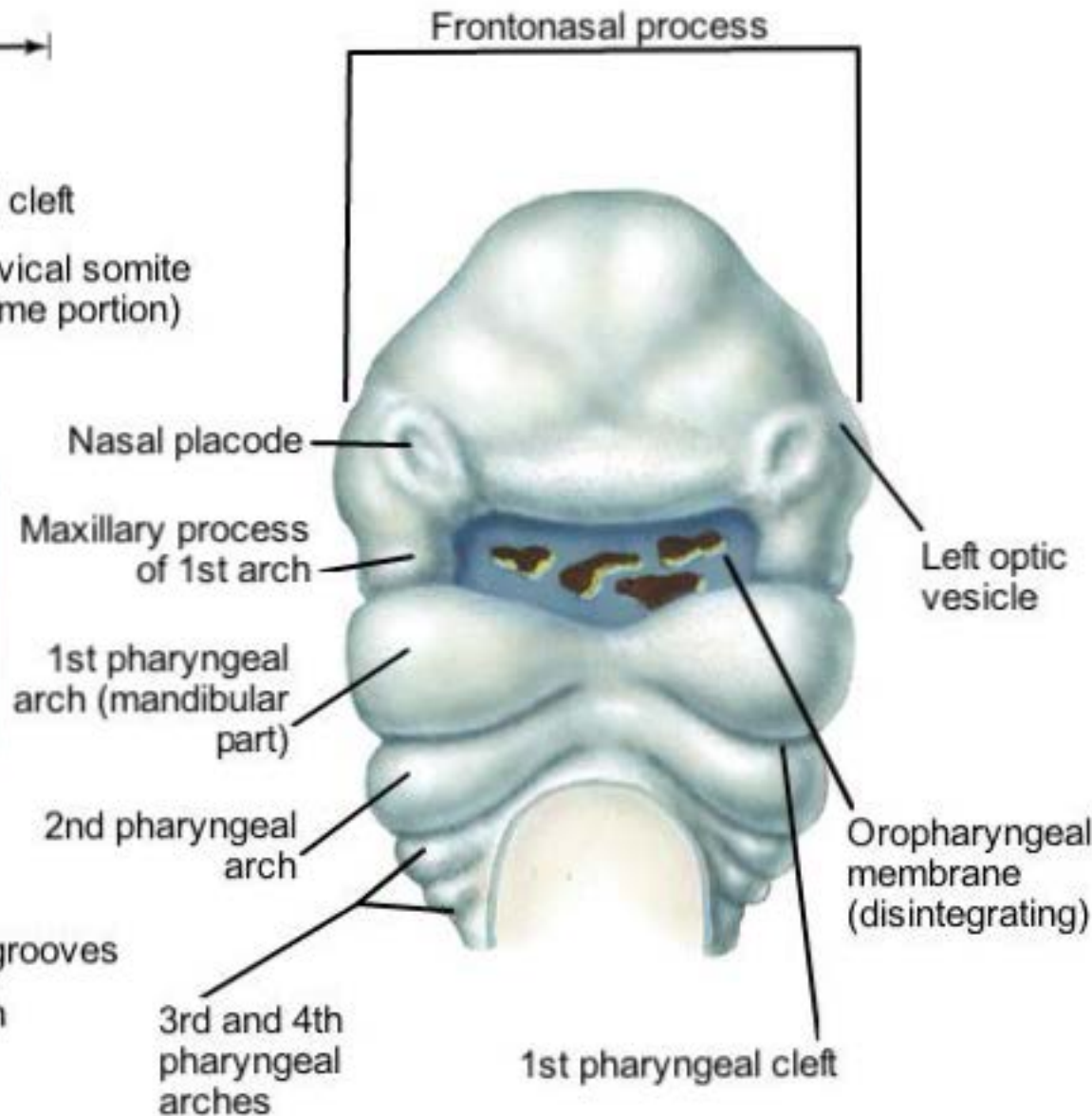


# Early Development of the Face: 4 to 6 Weeks

Lateral view at 4 to 5 weeks



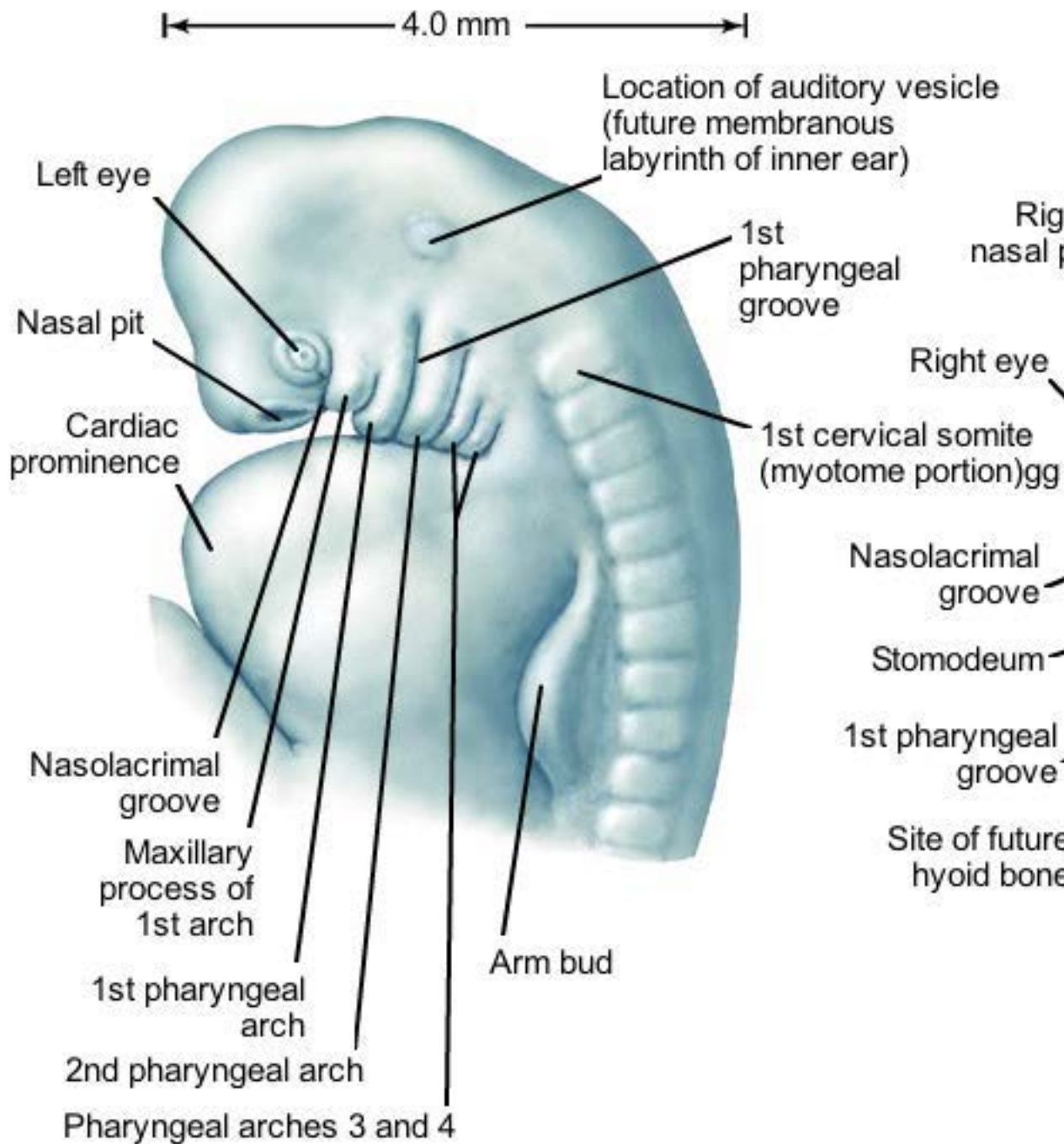
Ventral view at 4 to 5 weeks



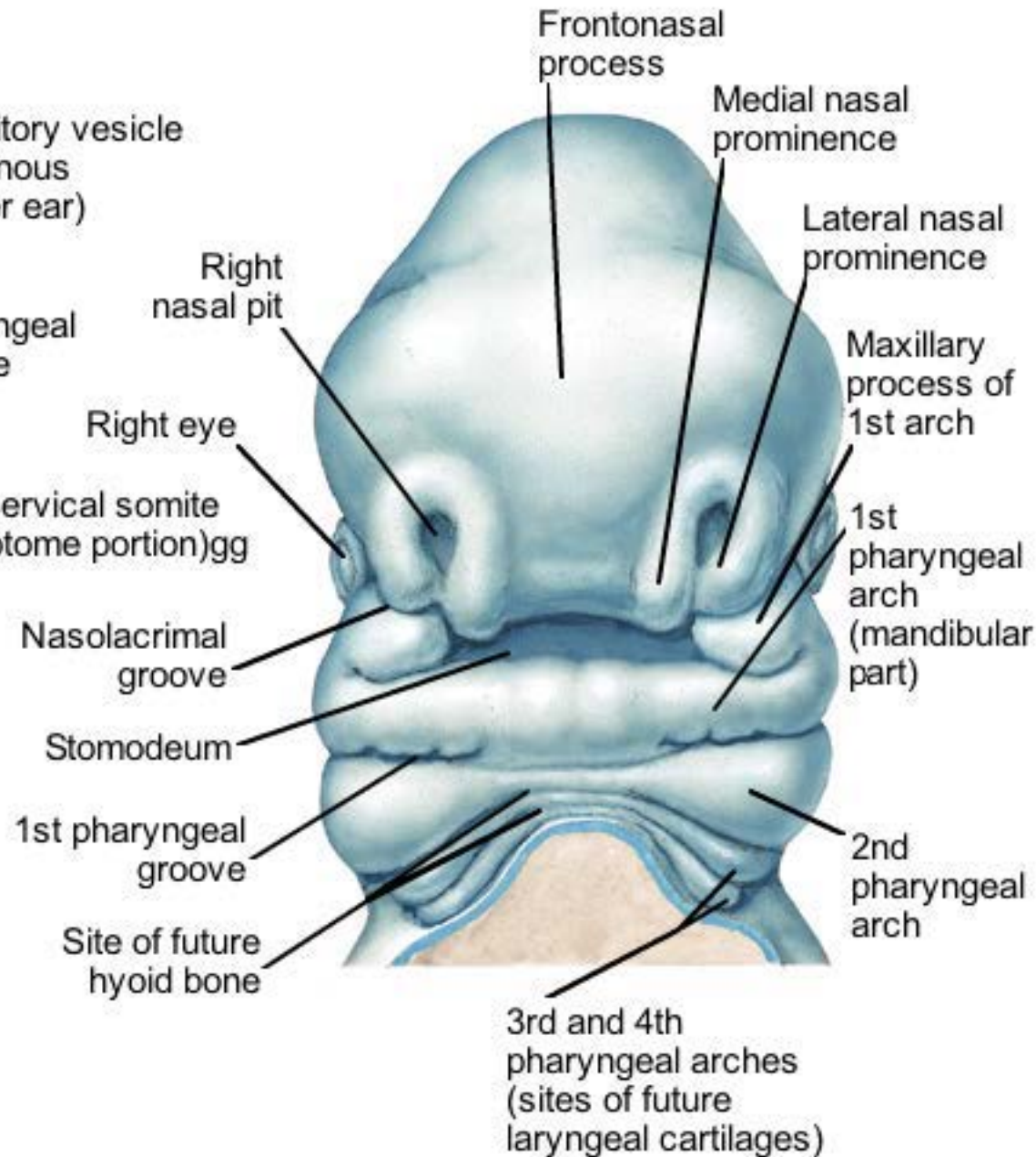


# Early Development of the Face: 4 to 6 Weeks

Lateral view at 5 to 6 weeks

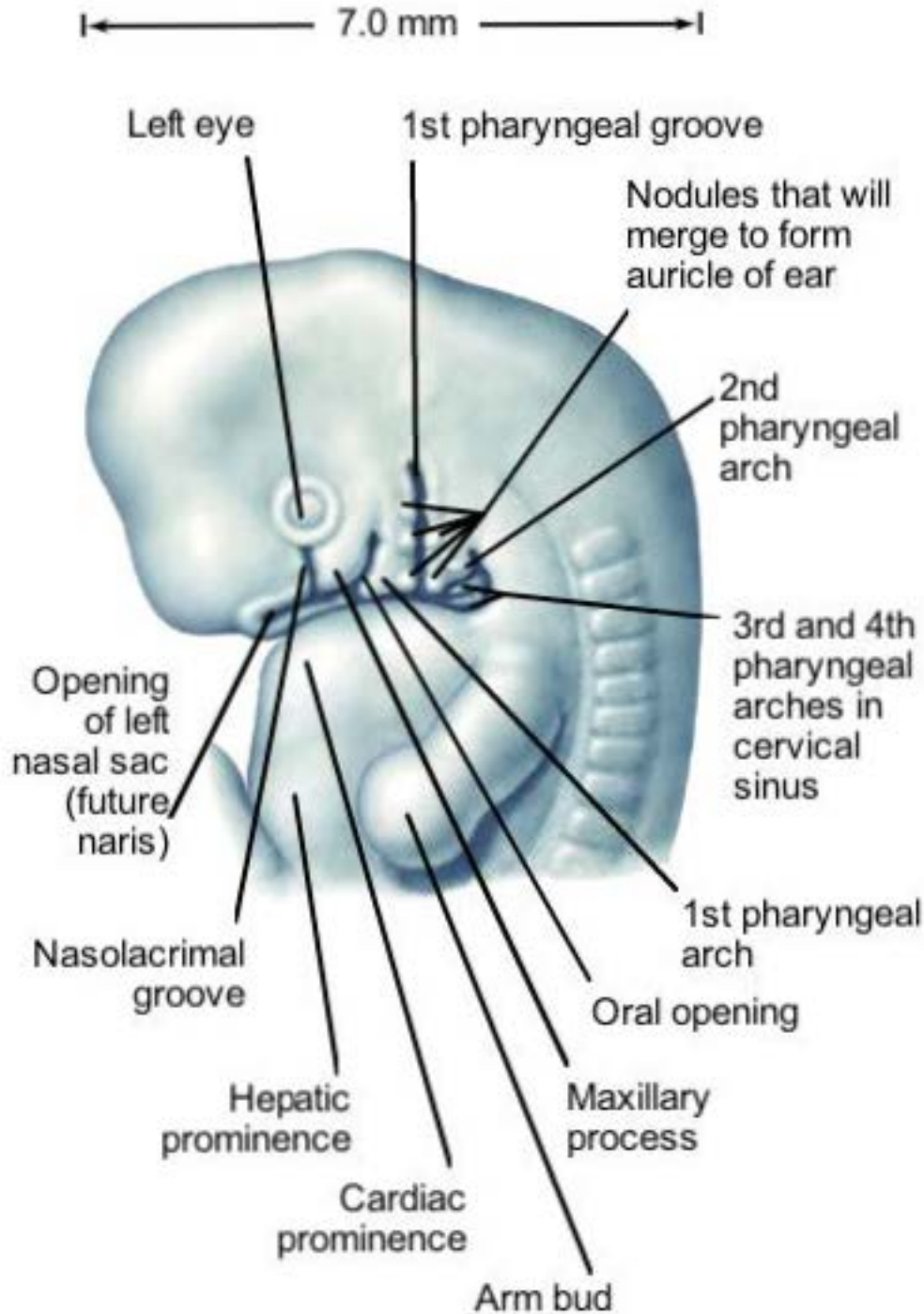


Ventral view at 5 to 6 weeks

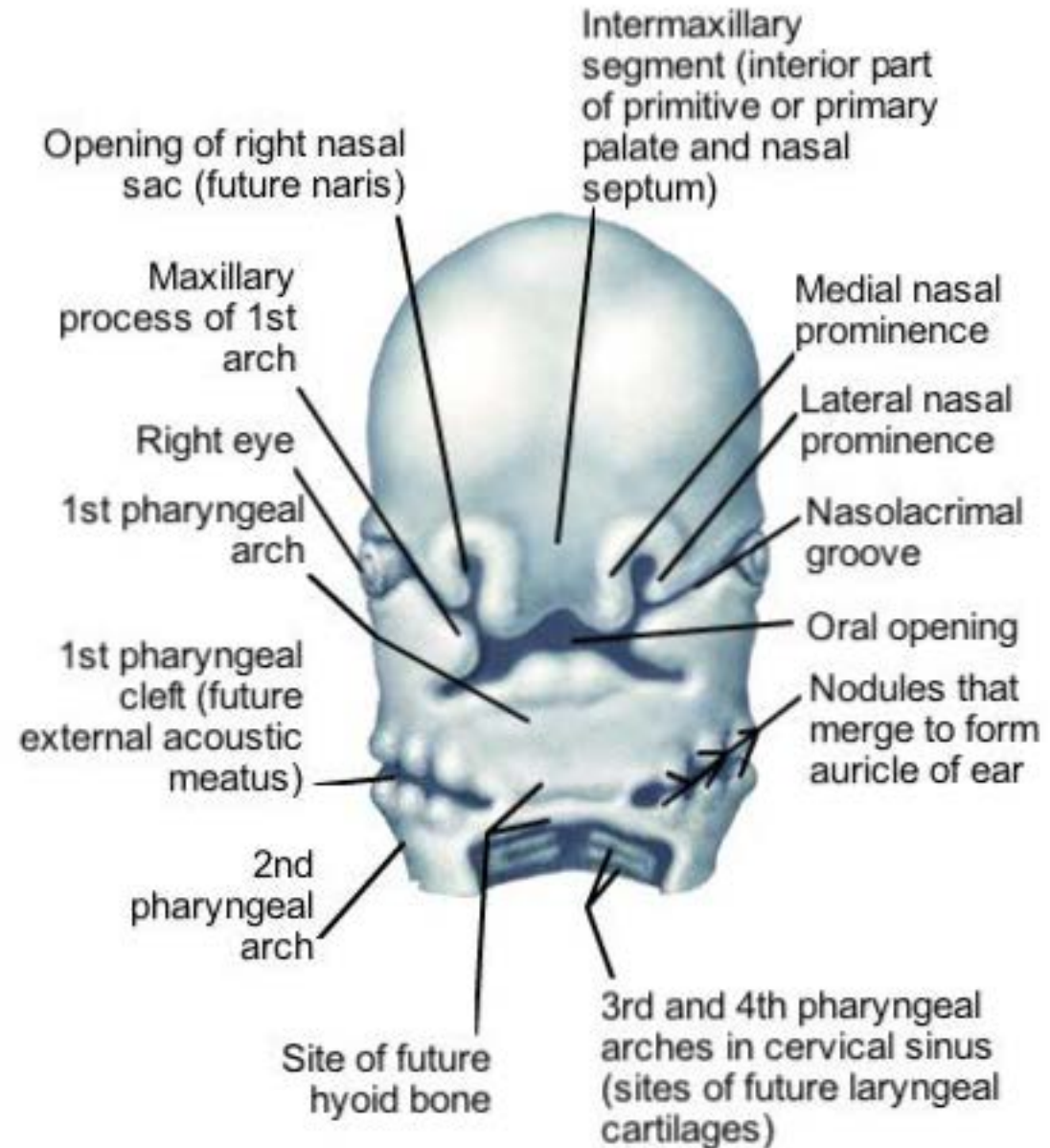


# Later Development of the Face

Lateral view at 6 to 7 weeks



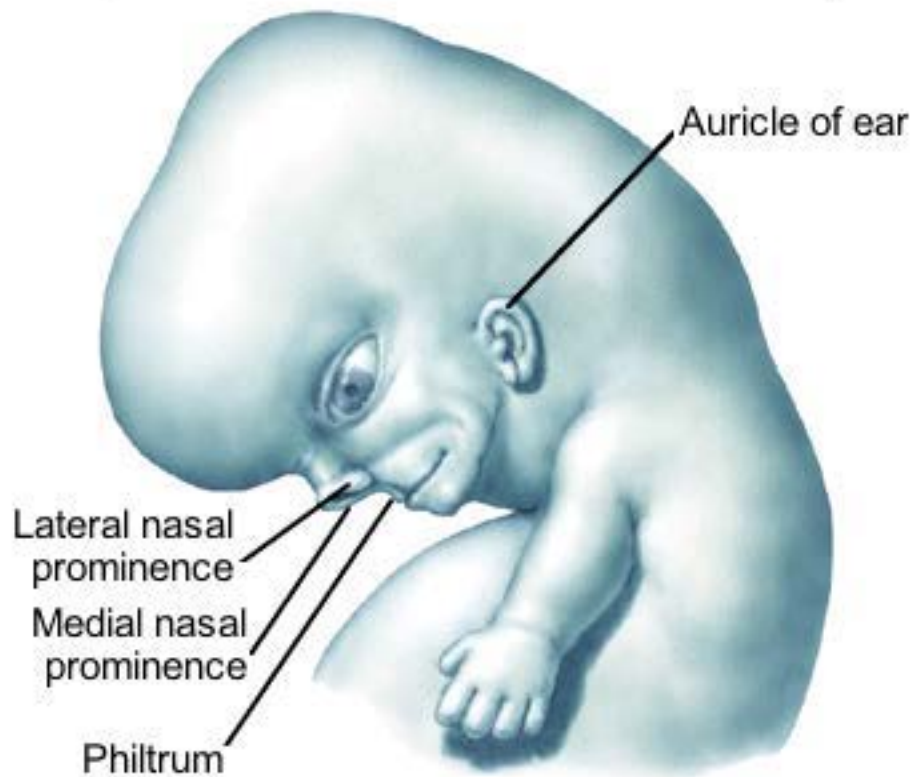
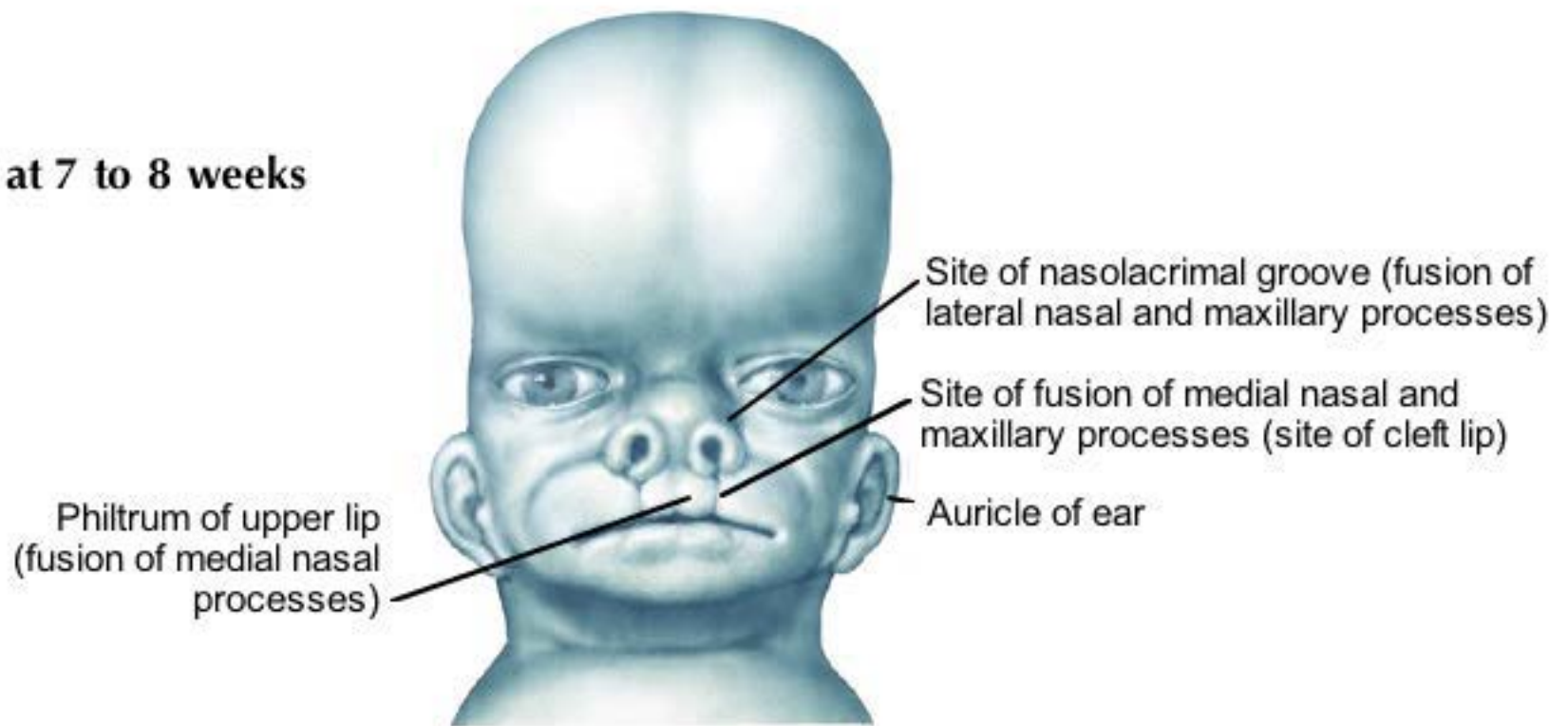
Ventral view at 6 to 7 weeks



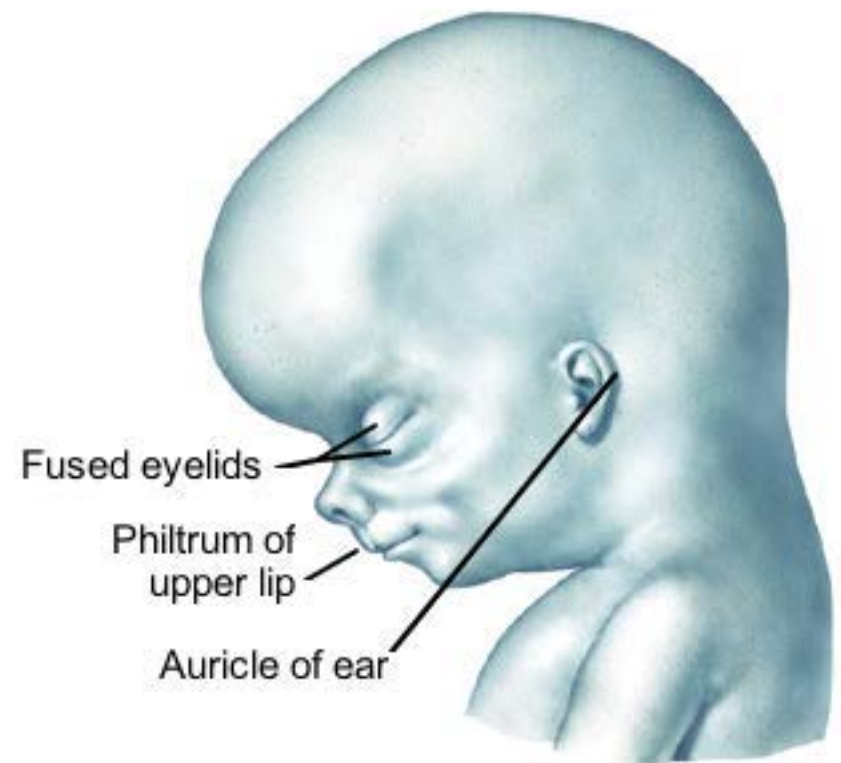


# Later Development of the Face

**Ventral view at 7 to 8 weeks**



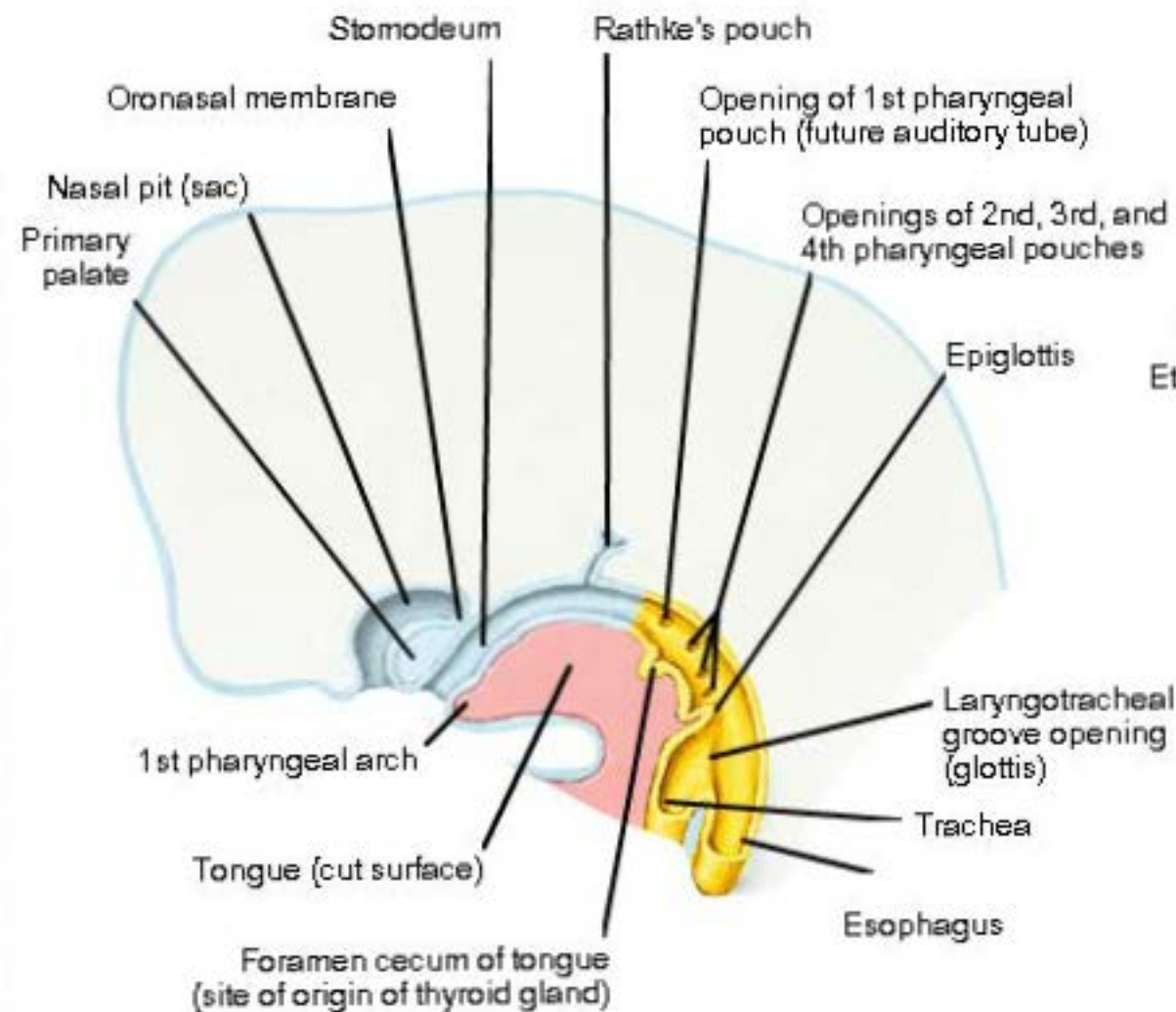
**Lateral view at 7 to 8 weeks**



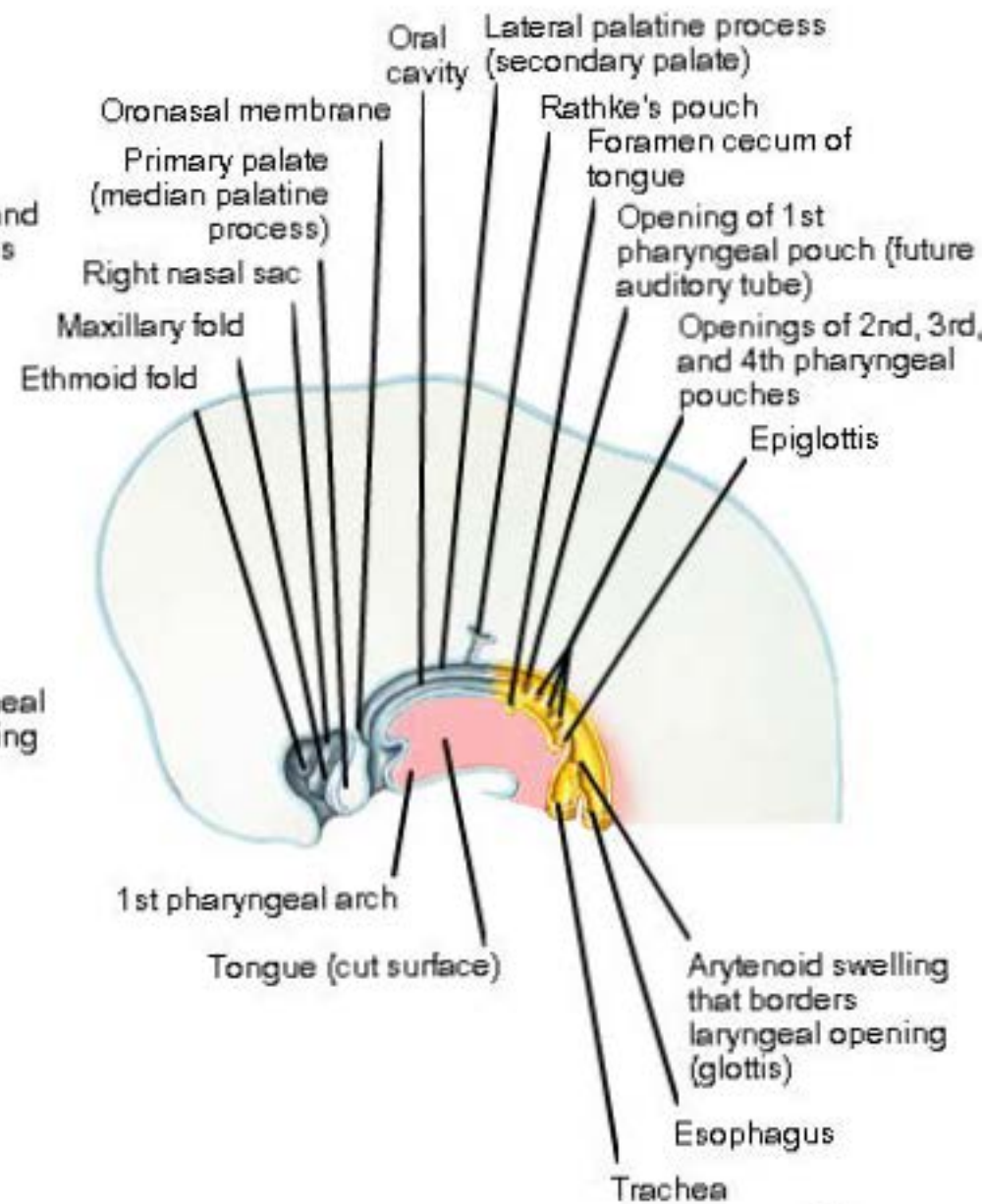
**Lateral view at 8 to 10 weeks**

# Palate Formation

Sagittal section at 5 to 6 weeks



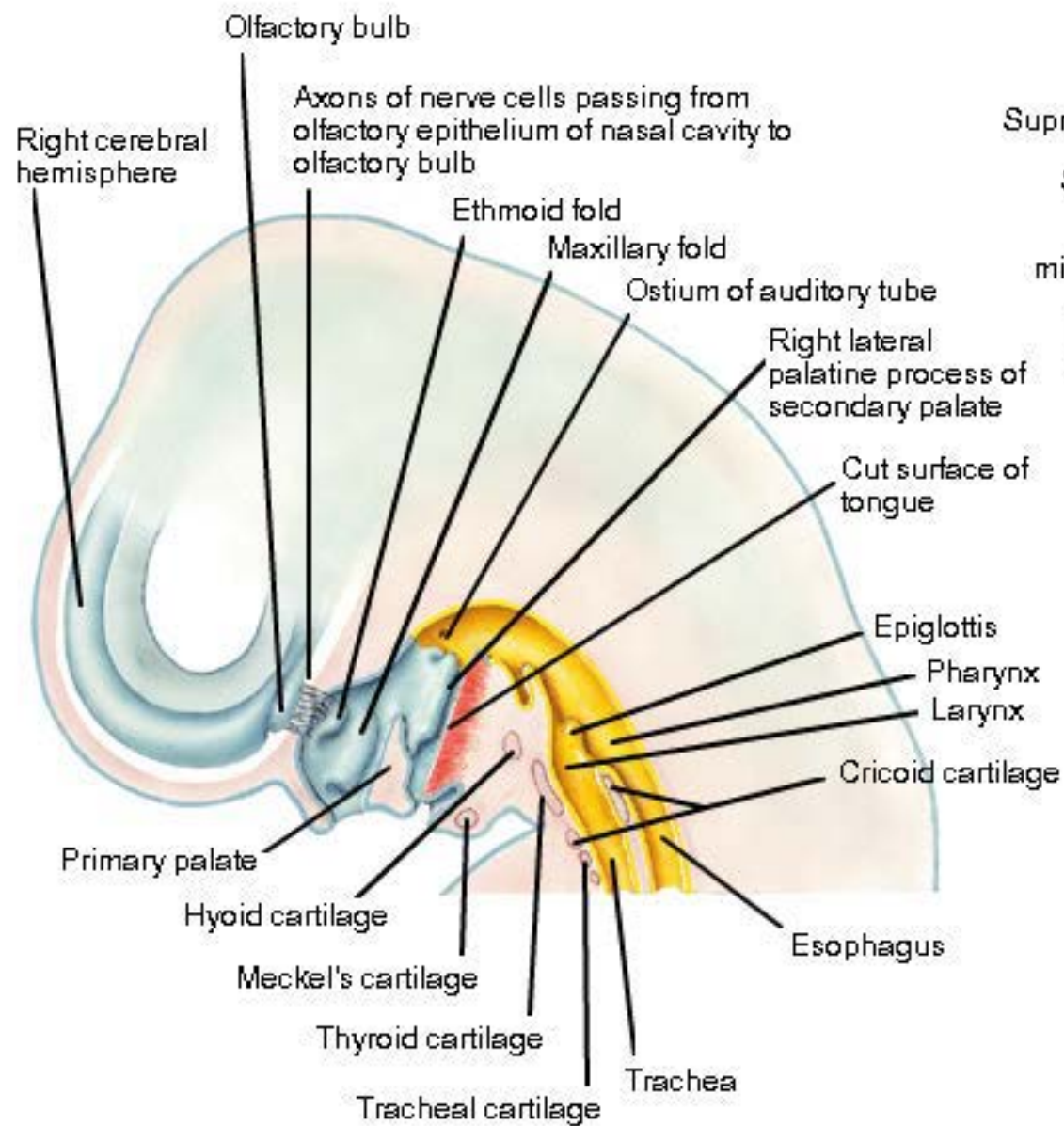
Sagittal section at 6 to 7 weeks



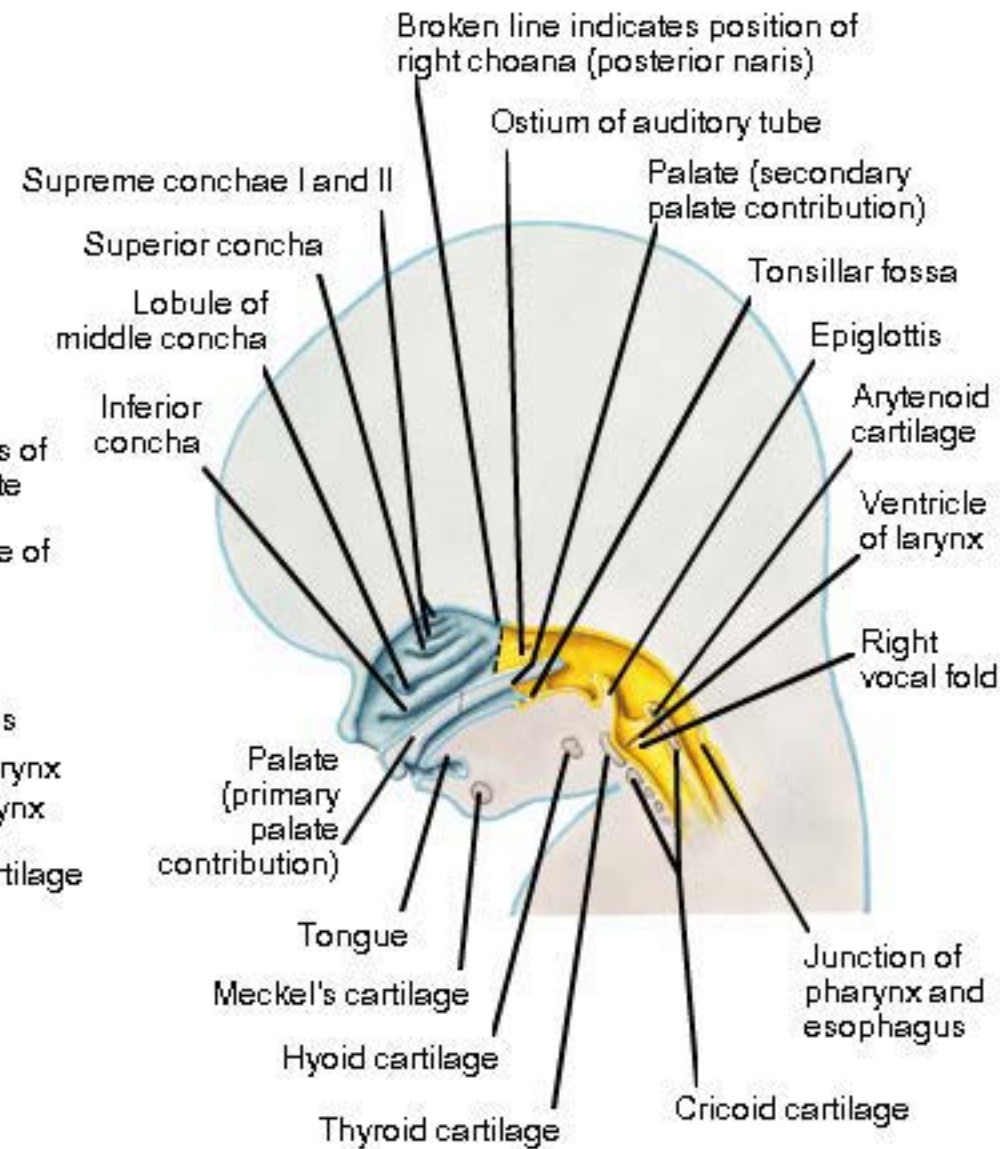


# Palate Formation

**Sagittal section at 7 to 8 weeks**

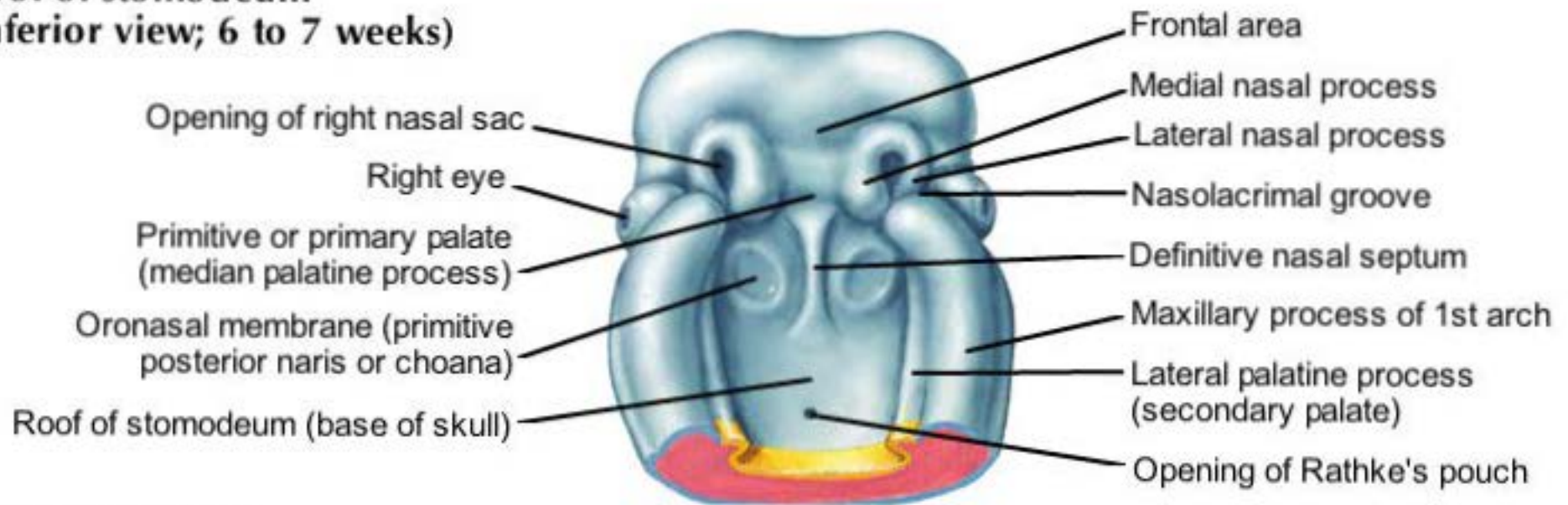


**Sagittal section at 8 to 10 weeks**

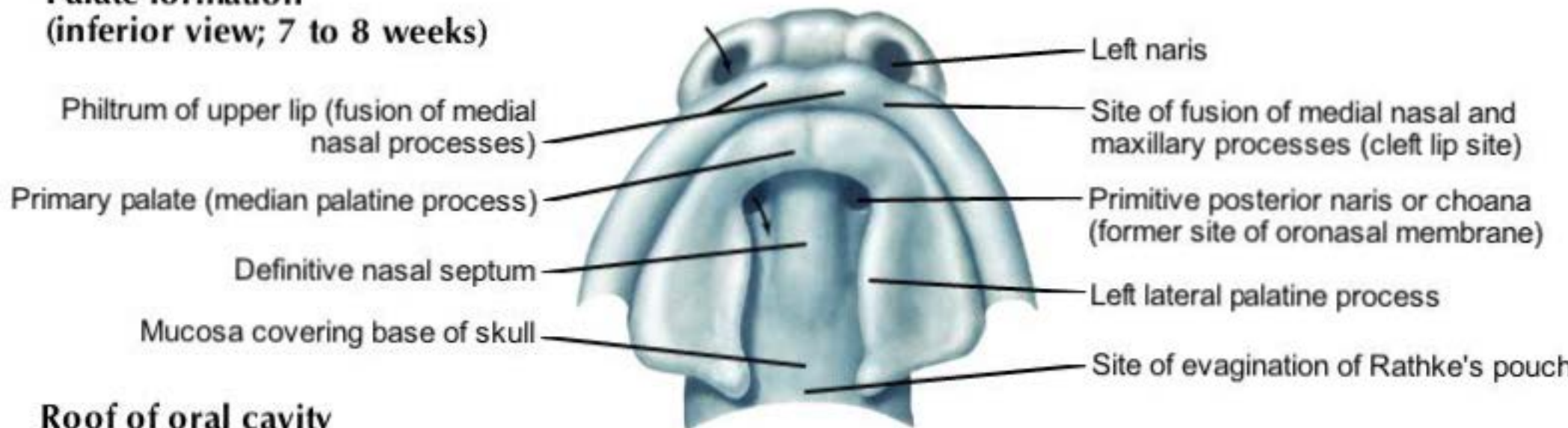


# Interior View of Palate Formation

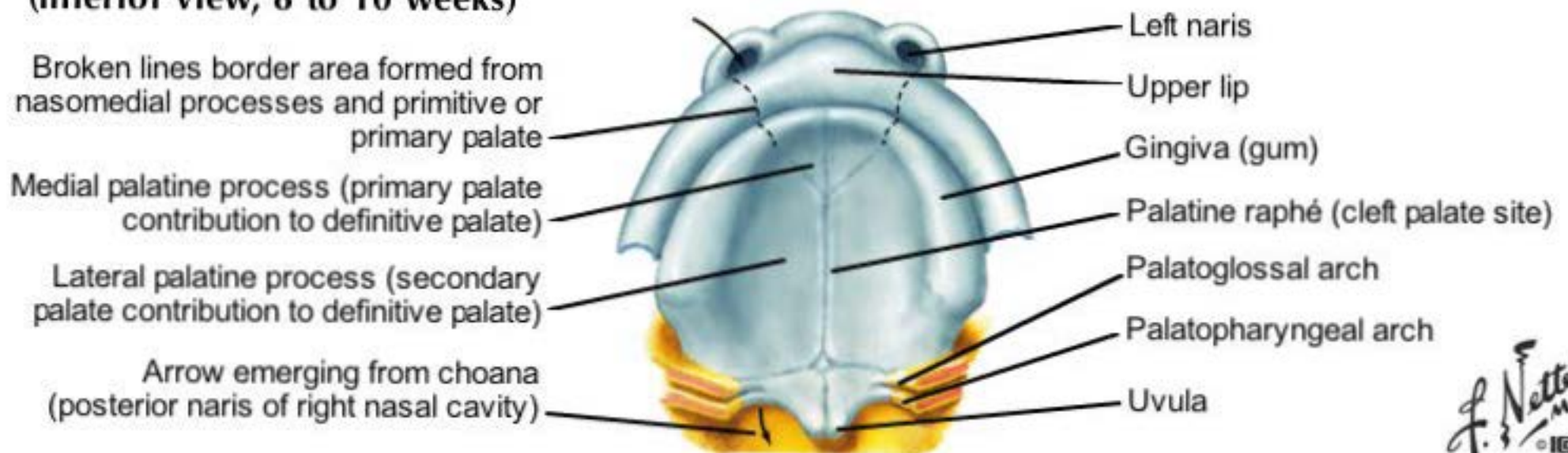
## Roof of stomodeum (inferior view; 6 to 7 weeks)



## Palate formation (inferior view; 7 to 8 weeks)



## Roof of oral cavity (inferior view; 8 to 10 weeks)





# Congenital Anomalies of the Oral Cavity

Unilateral cleft lip-  
partial



Unilateral cleft of  
primary palate-  
complete, involving  
lip and alveolar ridge



Bilateral cleft lip



Ankyloglossia-  
restricted tongue  
movement from a  
short lingual  
frenulum



Partial cleft  
of palate



Complete cleft of  
secondary palate  
and unilateral cleft  
of primary palate



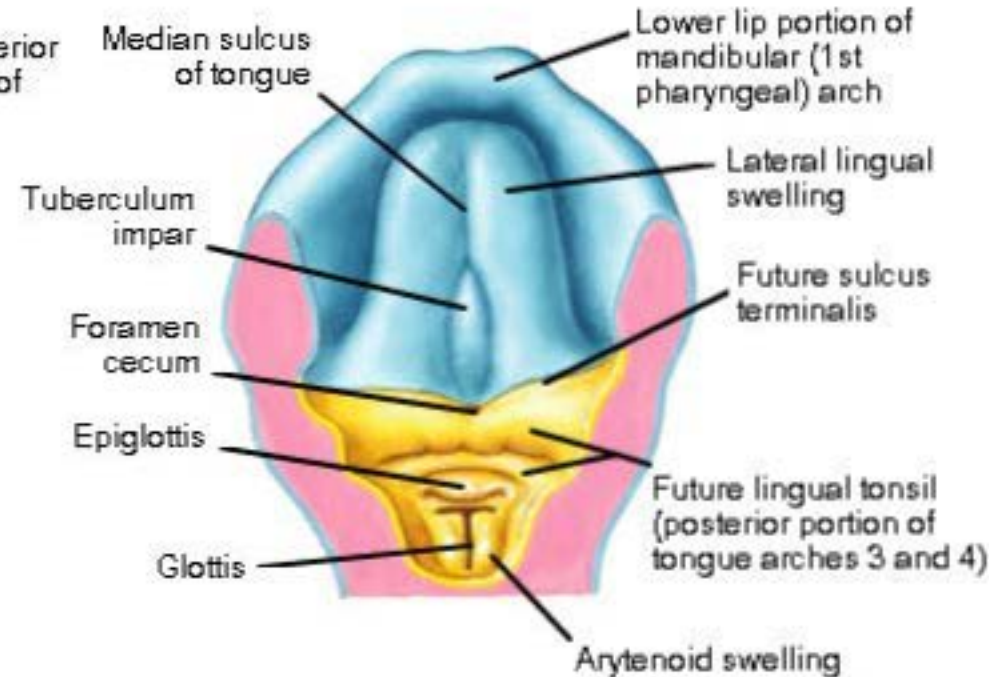
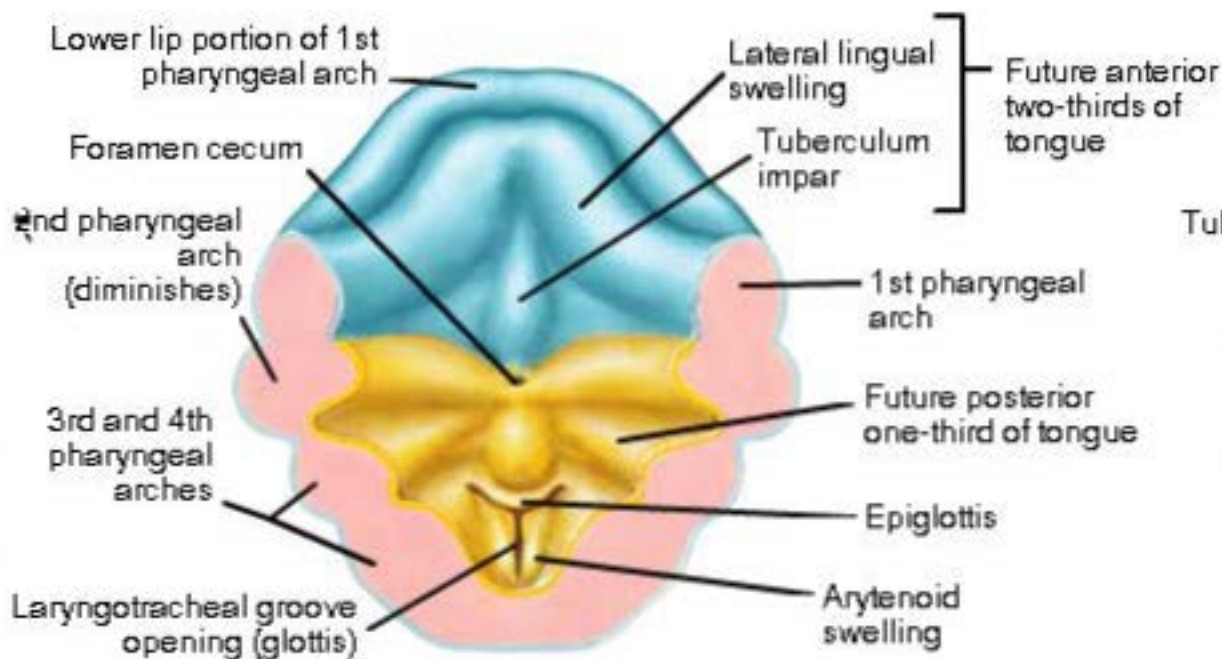
Torus palatinus-bone  
deposition on palate



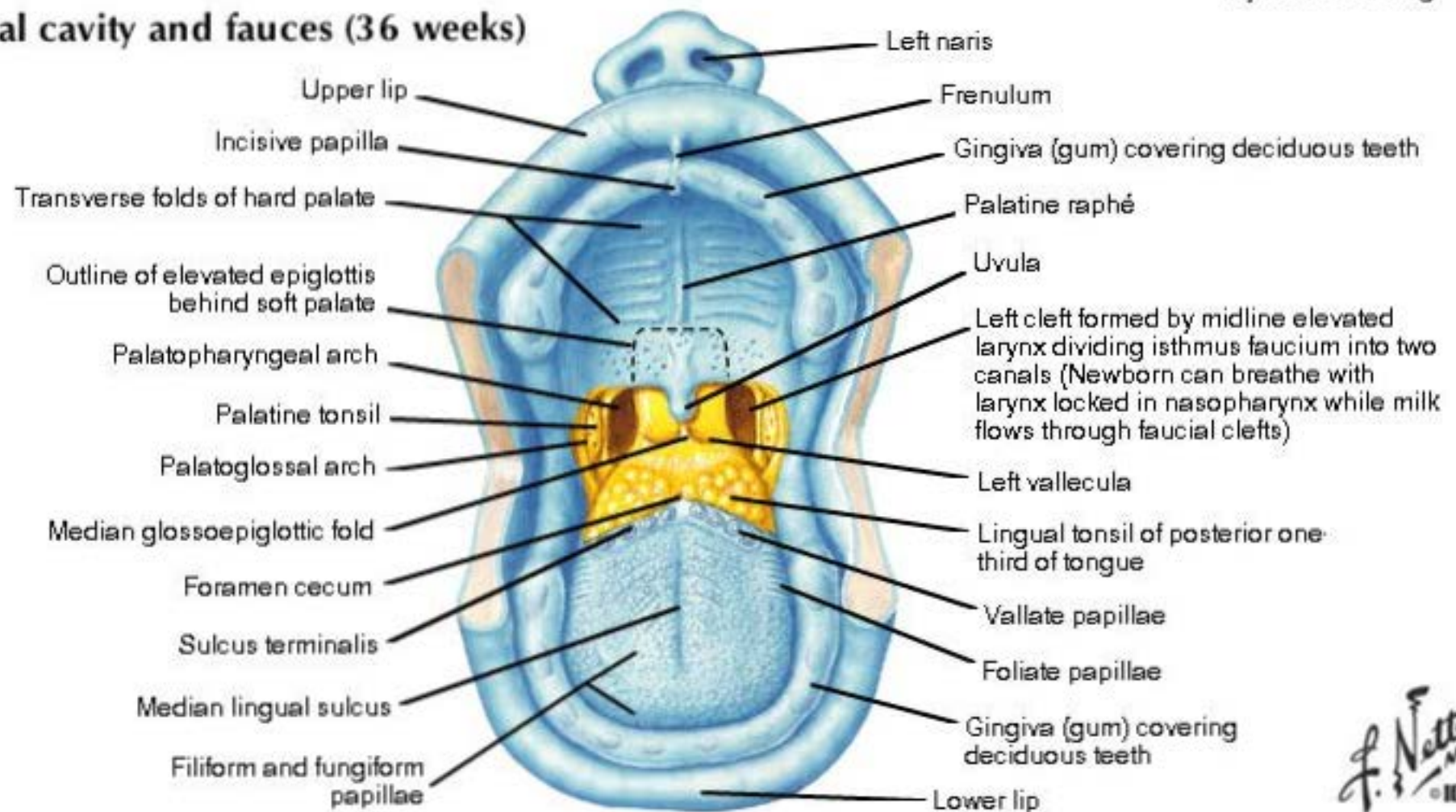
# Floor of the Oral Cavity

**Floor of oral cavity and pharynx  
(superior view; 5 to 6 weeks)**

**Floor of oral cavity and pharynx  
(superior view; 6 to 7 weeks)**



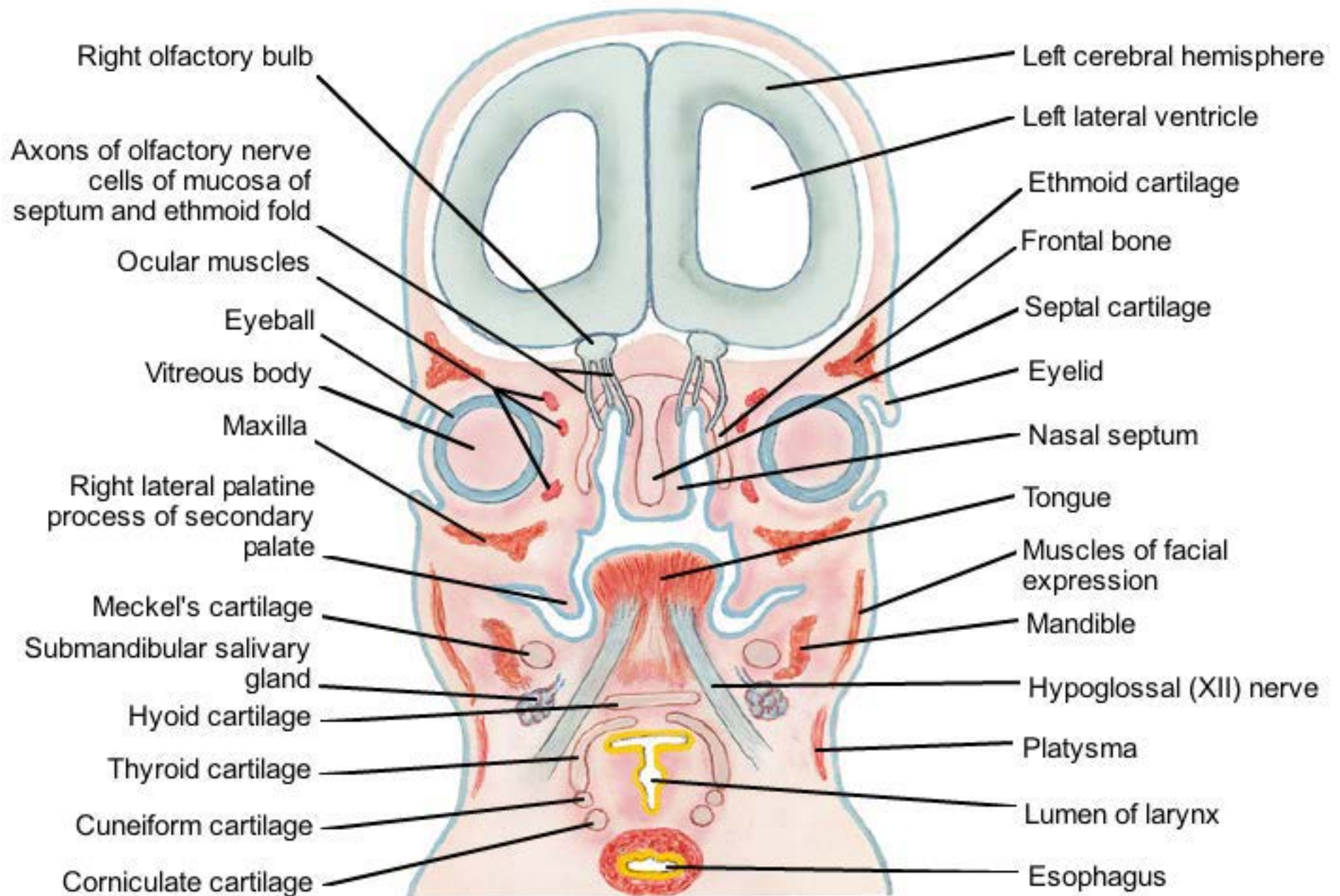
**Oral cavity and fauces (36 weeks)**





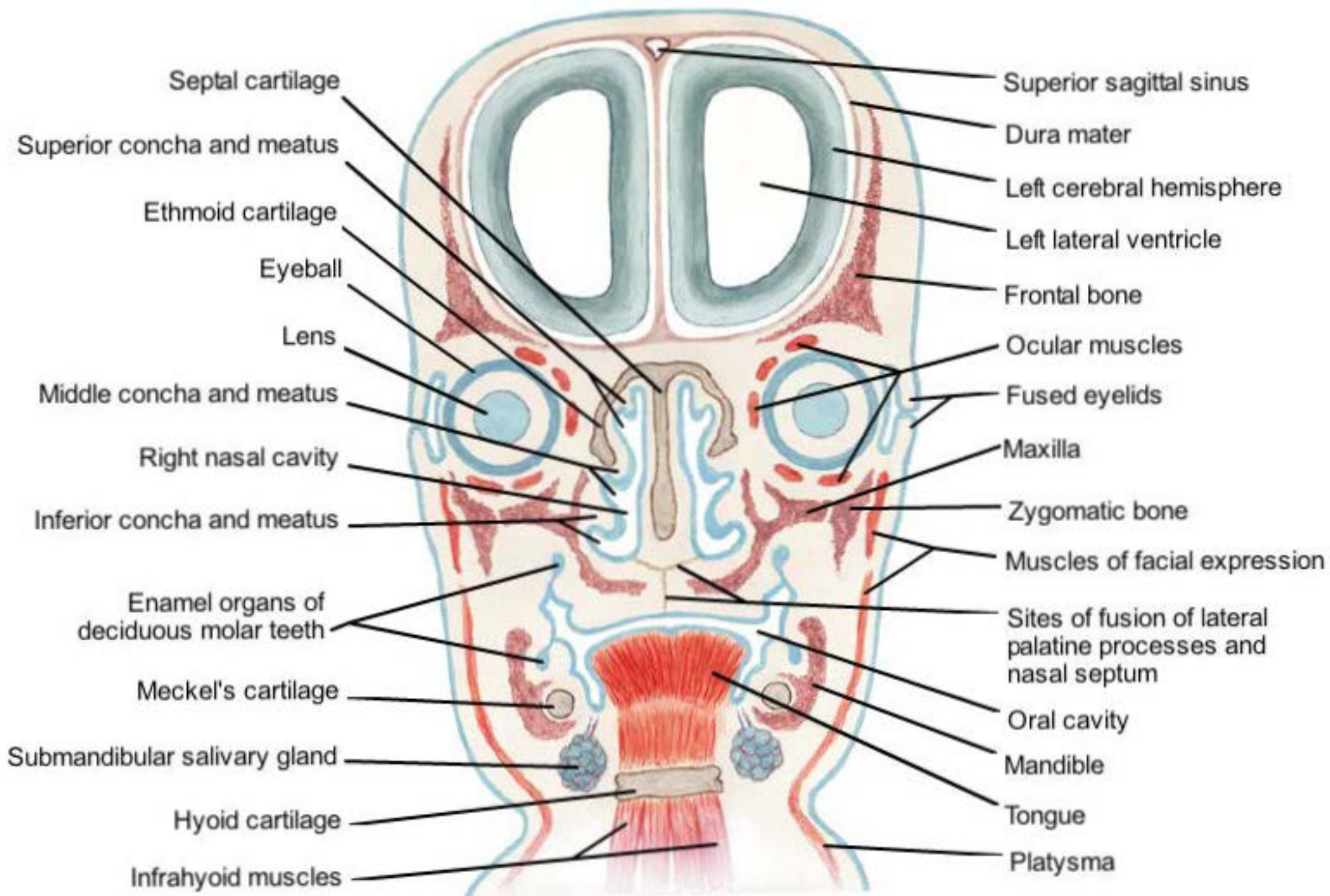
# Developmental Cross Sections

## Frontal (coronal) section at 7 to 8 weeks



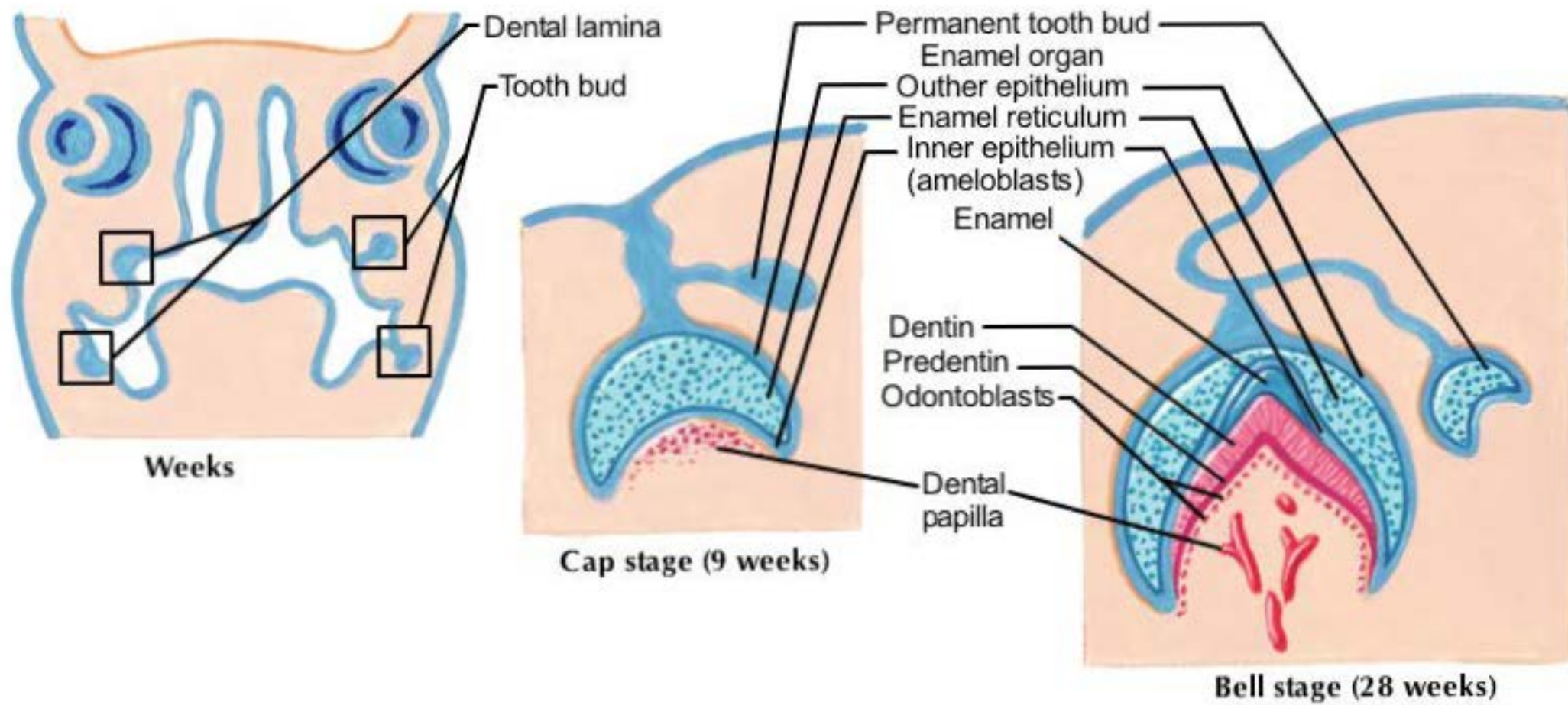
# Developmental Cross Sections

## Frontal (coronal) section at 8 to 10 weeks



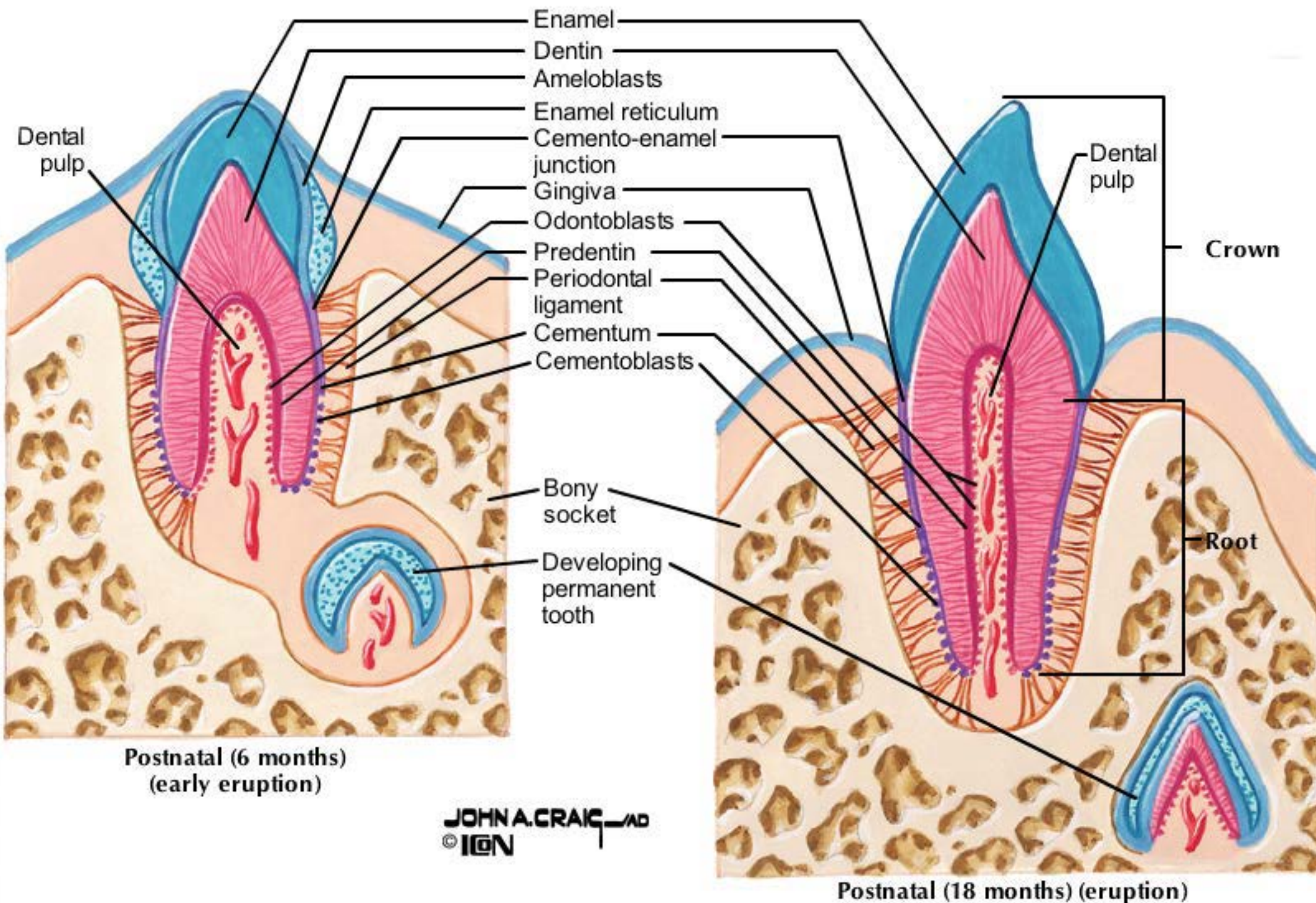


# Tooth Development





# Tooth Development





# Dental Eruption

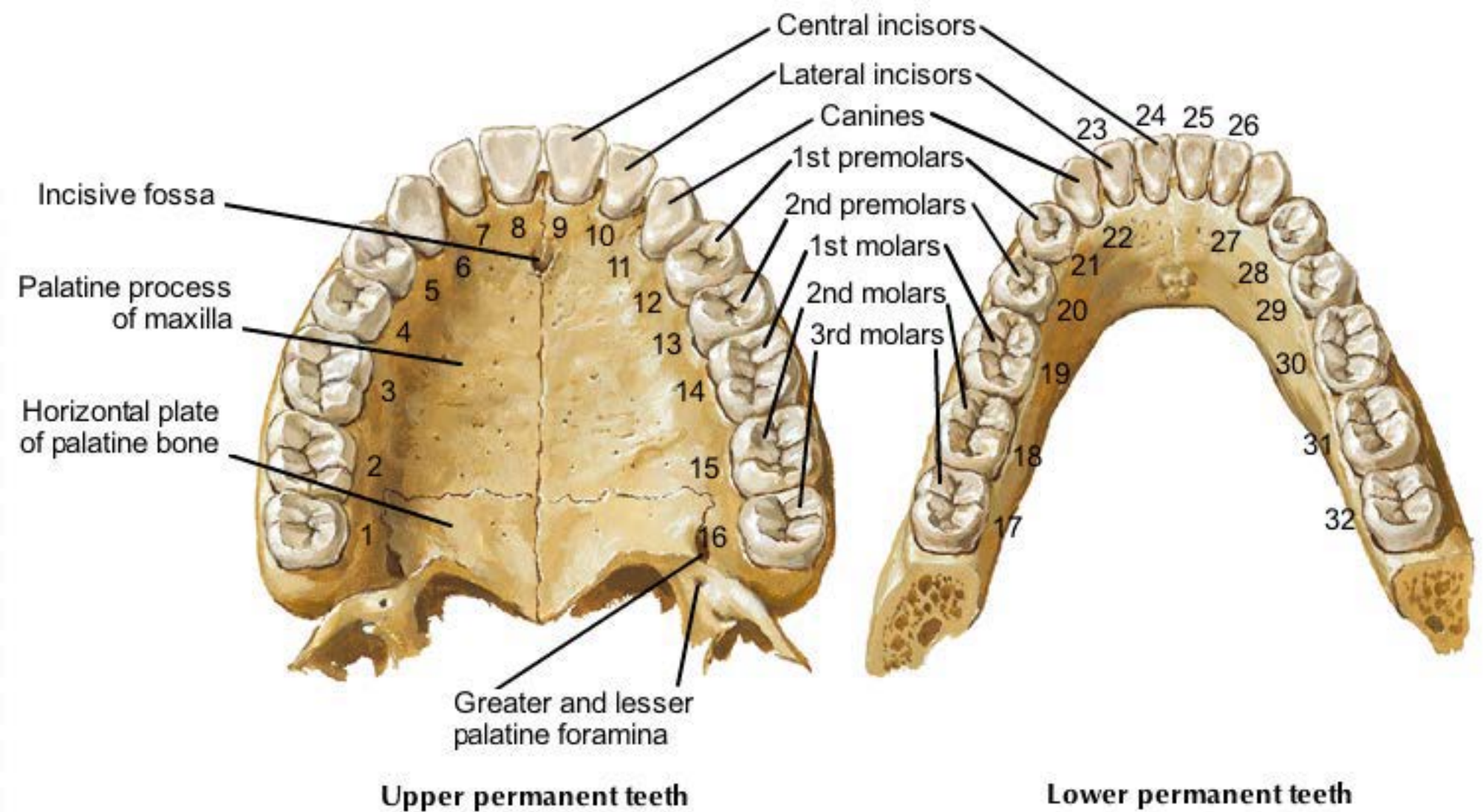
**Deciduous  
(primary)**  
Usual age of  
eruption

**Permanent  
(colored blue)**  
Usual age of  
eruption

Central incisor (8-10 months)  
Lateral incisor (8-10 months)  
Canine (cuspid) (16-20 months)  
1st molar (15-21 months)  
2nd molar (20-24 months)  
2nd molar (20-24 months)  
1st molar (15-21 months)  
Canine (cuspid) (15-21 months)  
Lateral incisor (15-21 months)  
Central incisor (6-9 months)

Central incisor (7th year)  
Lateral incisor (8th year)  
Canine (cuspid) (11th-12th year)  
1st premolar (9th year)  
2nd premolar (10th year)  
1st molar (6th year)  
2nd molar (12th-13th year)  
3rd molars (17th-25th year)  
2nd molar (12th-13th year)  
1st molar (6th year)  
2nd premolar (10th year)  
1st premolar (9th year)  
Canine (cuspid) (11th-12th year)  
Lateral incisor (8th year)  
Central incisor (7th year)

# Dental Eruption



**Note:** Numbers refer to a common scheme dentists use to identify teeth.  
(Letters are used for the deciduous definition.)



# Pharyngeal Pouch and Groove Derivatives

No.	From Pouches	From Grooves
1	Auditory tube, middle ear cavity, mastoid air cells	External auditory meatus
2	Palatine tonsil crypts	Cervical sinus (disappears)
3	Inferior parathyroids, thymus	Cervical sinus (disappears)
4	Superior parathyroids, parafollicular cells (C cells) of thyroid	Cervical sinus (disappears)

# Ear Structures and Their Primordia

Structures	Primordia
Auricle	Mesenchyme of the 1st and 2nd pharyngeal arches
External auditory meatus	1st pharyngeal groove (ectoderm)
Middle ear cavity; auditory tube, mastoid air cells	1st pharyngeal pouch (endoderm)
Cochlea and semicircular canals	Otic placode/otocyst (ectoderm)
Tympanic membrane	1st pharyngeal membrane (ectoderm/endoderm) with intervening mesenchyme
Ear ossicles	1st pharyngeal arch cartilage (incus and malleus) 2nd pharyngeal arch cartilage (stapes)
Temporal bone	Occipital sclerotomes (mastoid and petrous parts) 2nd pharyngeal arch cartilage (styloid process) 1st pharyngeal arch mesenchyme (squamous and tympanic parts)



# Special sensory and Somatomotor Cranial Nerve Components

Nerve	Primordium Innervated	Neuron Components
Olfactory (I) Optic (II) Vestibulocochlear (VIII)	Olfactory placode Optic cup Otic placode	Special sensory (olfaction) Special sensory (vision) Special sensory (hearing and balance)
Oculomotor (III)  Trochlear (IV) Abducens (VI) Hypoglossal (XII) Accessory (XI)	Preotic somitomere  Preotic somitomere Preotic somitomere Postotic somites Somitic mesenchyme by arch 6	Somatomotor to extraocular eye muscles Parasympathetics to ciliary ganglion (for pupil constrictor and ciliary muscle) Somatomotor to superior oblique muscle Somatomotor to lateral rectus muscle Somatomotor to tongue muscles Somatomotor to sternocleidomastoid and trapezius

# Pharyngeal Arch Cranial Nerve Components

Nerve	Arch	Neuron Components
Trigeminal (V)	1	General sensory (face, orbit, nasal and oral cavities) Branchiomotor (muscles of mastication; tensor tympani; tensor veli palatini)
Facial (VII)	2	Branchiomotor (muscles of facial expression; stylohyoid; posterior digastric; stapedius) Special sensory (taste to anterior two-thirds of tongue) Parasympathetic to pterygopalatine and submandibular ganglia (for lacrimal gland, nasal mucosa, and salivary glands)
Glossopharyngeal (IX)	3	Visceral sensory to pharynx Branchiomotor to stylopharyngeus Parasympathetic to otic ganglion (for the parotid gland) Special sensory (taste to posterior tongue; carotid body and sinus)
Vagus (X)	4 and 6	Branchiomotor (pharynx and larynx) Visceral sensory (larynx; foregut below pharynx and midgut) General sensory to external acoustic meatus Parasympathetics (enteric ganglia of foregut and midgut) Special sensory (taste in laryngopharynx; carotid body and sinus)



# Innervation of the Tongue

## INNERVATION OF THE TONGUE

Anterior two-thirds (oral cavity)	General sensory (GSA)—lingual branch of V3 Taste (SVA)—facial nerve (VII)
Posterior one-third (oropharynx)	Visceral sensory (GVA)—glossopharyngeal nerve (IX) Taste (SVA)—glossopharyngeal nerve (IX)
Root (laryngopharynx)	Visceral sensory (GVA)—vagus nerve (X) Taste (SVA)—vagus nerve (X)
Tongue muscles	Somatomotor—hypoglossal nerve (XII)

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